Risk Assessment Report
Honolulu High-Capacity Transit Corridor Project

January 5, 2011
FINAL DRAFT

January 2011

Prepared for:
City and County of Honolulu

Preface

Parsons Brinckerhoff (PB), engaged by the grantee, the City and County of Honolulu (City) Rapid Transit Division (RTD), has conducted a risk assessment for the Honolulu High-Capacity Transit Corridor Project (the Project).

The objective is to support the Project's application for entry into Final Design. The Federal Transit Administration (FTA) and its Program Management Oversight Contractor (PMOC) have been provided full access to the process, interviews, and workshops, and their input, comments, and suggestions have been considered as part of this process and analysis.

The risk assessment has been carried out in line with FTA's risk assessment guidelines outlined in Oversight Procedure 40.

The process for the study can be summarized as follows:

- Pre-workshop site tour, project familiarization with the PB Team, and pre-workshop interviews with key PB, RTD, and City project staff (commencing April 2010)
- Review line capacity, environmental documents, Project Management Plan, estimates, and schedule
- Prepare draft cost and schedule risk models
- Review existing project risk register
- Facilitate a number of risk workshops with project team members reviewing line capacity, agency capacity, the National Environmental Policy Act (NEPA), scope, cost, schedule, and mitigation opportunities
- Update project risk register addressing Sectional and project completion dates
- Upon completion of workshops, complete risk modeling and draft report incorporating agency-proposed cost and schedule draw-down contingency profiles with minimum contingency levels at "hold points"
- Discuss results internally and then present and discuss with FTA/PMOC; address any concerns and comments; and issue final report in support of City's application to enter Final Design

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Third-Party Disclaimer

The structured process by which this study has been undertaken with the involvement, consideration, and agreement in the analysis and results of the study by the study participants provides the best current assessment of the City and County of Honolulu's exposure to risk. Risk exposure, however, is by its nature subjective. The risk exposure of the Project will continuously evolve, and this report represents the best assessment at the date of the report and associated study interviews and workshops. The assessment is provided with the objective to assist the City with a more informed decision-making process.

The risk assessment records and models the views of the City, RTD, and the Project Team at the risk workshops and as may be recorded in prior or subsequent meetings. The risk assessment addresses, at a point in time, issues that could arise on the Project given the experiences of the Project Team associated with the study. It is limited in scope in respect to time allotted to the study, information available at the time of the study, and availability of the Project Team and external technical expert representation during the study. There is no given undertaking that all risks have been identified or, indeed, that the quantification of the risks is in any way a guarantee of limit of exposure to schedule delay or cost overrun or under run to the City.

Exclusions and Assumptions

The risk analysis is based on the following assumptions/exclusions:

- The Quantitative Cost and Schedule Risk Analysis is based on credible ranges of costs and possible schedule deviations.
- The risk study does not deal with extreme events such as wars, serious earthquakes, or stock market crashes, multiple deaths/injuries from site accident(s)/acts of God, and the like.
- The financial plan assumes that the City will allocate 5307 formula funds to rail capital costs, which is an eligible use for these funds. These funds are currently used to support bus capital costs. The risk assessment assumes these funds will be available as assumed in the financial plan. The Council will have to appropriate these funds for this purpose once the transit agency becomes a separate authority, as it would for all of the Project's capital funding sources; however, no risk is included for this future appropriation.
- The financial plan addresses risks associated with the timing and availability of funding sources. This risk analysis and risk register do not contain funding-related risks. Any risks related to funding of the Project are incorporated into the FMO review process.

- No permanent remote additional parking will be provided by the City for communities along the alignment. Temporary parking will be provided if current facilities are required during construction.
- The risk assessment assumes that the Record of Decision (ROD) will be signed on or before March 1, 2011. Any delay beyond this date will result in the risk analysis not supporting the resulting extended schedule and cost increases. It is assumed in such an event that the basis of schedule, contracting packaging strategy, and financial plan would require a complete review.
- The risk assessment does not take into consideration a return to the Salt Lake alignment option (as included in the environmental impact statement).
- The risk assessment assumes no additional entrances will be provided at Middle Street.
- The risk assessment assumes no additional scope will be added in connection with accommodating future airport access or expansion plans over and above that scope currently shown on the drawings.

Report History Log

Rev #	Date Issued	Status	Comments
0	December 3, 2010	1st draft for review	Draft report compiled and issued to PB for internal review prior to formal passing to RTD and the City and County of Honolulu. Not QA/QC'd.
1	December 17, 2010	2nd draft for review	Draft report issued to RTD and the City of Honolulu for review
2	January 4th, 2011	3rd Draft for review	Draft report updated incorporating RTD comments as discussed January 4th 2011

Acronyms and Abbreviations

BAFO	best and final offers
BCE	budget cost estimate
BRF	beta range factor
CE&I	construction engineering and inspection
FFGA	Full Funding Grant Agreement
FTA	Federal Transit Administration
GBR	Geotechnical Baseline Report
HECO	Hawaiian Electric Company
HHCTCP	Honolulu High-Capacity Transit Corridor Project
LONP	letter of no prejudice
MSF	maintenance and storage facility
NEPA	National Environmental Policy Act
OCIP	owner controlled insurance program
PB	Parsons Brinckerhoff
PE	Preliminary Engineering
PMOC	project management oversight contractor
RCD	revenue commencement date
ROD	Record of Decision
ROW	right-of-way
RTD	Rapid Transit Division
SCC	standard cost category
WOFH	West O‘ahu/Farrington Highway
YOE	year of expenditure

1 Executive Summary

1.1 Risk Identification

The top five risks to the Project can be summarized as follows in order of potential greatest severity:

- **Risk 467**—Given limited geotechnical information (e.g., widely spaced borings) available at this time, additional costs may be incurred associated with differing subsurface conditions (City Center)
- **Risk 312**—City may require design changes to design-build submittals resulting in formal change orders (Core Systems Project Wide)
- **Risks 351, 353, 355, and 389**—State or Board of Water Supply may not grant waiver to leave in place existing utilities that are to be abandoned and are not affected by new structures, thereby requiring partial or total removal (Project Wide)
- **Risk 300**—Delay in issuing Notice to Proceed results in claims for additional costs (West Oʻahu Farrington Highway (WOFH)
- **Risk 252**—Soft costs—design, program management, construction management, and agency management—may be underestimated depending on schedule following ROD announcement (Project Wide)

The full risk register is incorporated into this report as Appendix B.

1.2 Cost Risk Analysis

The project's budget cost estimate (BCE) is currently $4.35 billion in 2010 and $5.167 billion in Year of Expenditure (YOE).

The bottom-up cost risk analysis provides a 70 percent confidence in completing the Project at or below the current BCE YOE of $5.167 billion. To reach an 80 percent confidence level, an additional $136 million in contingency is required.

The top-down cost risk analysis indicates the Project's current BCE YOE is below the calculated 30th percentile assumed target contingency at 40 percent bid of $5.311 billion and requires an additional $145 million in contingency. (The current milestone is viewed as 40 percent bid; however, the Beta Range Factors (BRF) are more representative on average of a project at entry into Final Design.) The Project does not fit into the FTA OP40 delivery cycle, as described in Section 6.2.

Secondary and tertiary mitigation capacity is outlined in Section 8.

The results of the cost risk assessment are summarized in Table 1-1 and Figure 1-1.

Table 1-1. Summary Cost Risk Analysis Results

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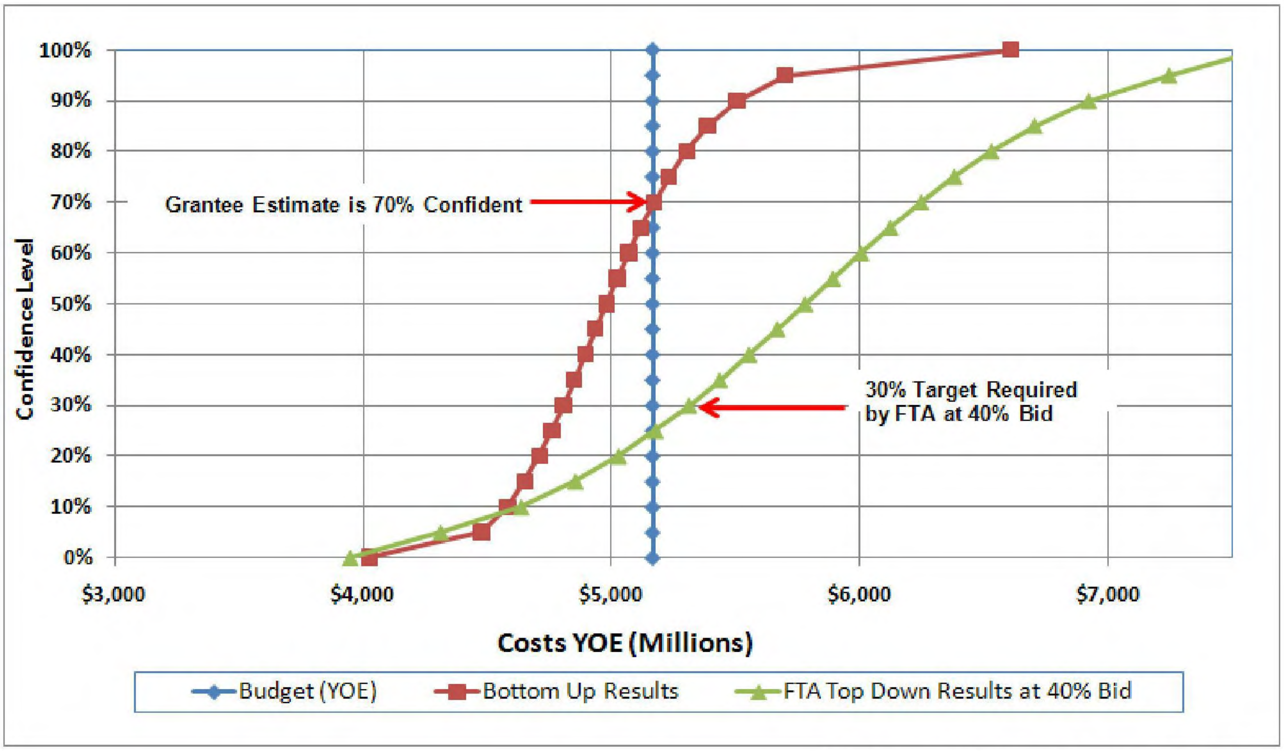

Figure 1-1. Cost Risk Analysis

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1.3 Schedule Risk Analysis

The City's current Revenue Commencement Date (RCD) is March 2019. The risk assessment on the current baseline described herein reports a RCD of January 2020 with a proposed planned targeted opening by August 2019.

The schedule risk assessment provides an 80 percent confidence in achieving a RCD on or before January 2020 and a 20 percent confidence of achieving a RCD by August 2019. The schedule, however, as described herein is based upon the Airport and City Center guideway sections being procured using a design/bid/build procurement approach with station design and procurement staggered to obtain the best possible bids. There is opportunity to bring the opening date forward through accelerating the procurement processes although these may have cost implications. There is an argument, however, that suggests the earlier the bids can be secured the less exposure there is to possible inflation in later years.

The RCD of January 2020 complies with the FTA's recommended minimum schedule float capacity at 100 percent bid calculated to be 16 months. The results of the schedule risk analysis are presented in Table 1-2 and Figure 1-2.

Table 1-2. Summary Schedule Risk Analysis Results

Confidence Level	Schedule Risk	Difference from Current RCD Date
Current RTD IPS RCD[1]	Mar-19	City Center/Project Completion
RTD proposed RCD with Buffer Float[2]	Jul-19	City Center/Project Completion
Proposed RCD with FTA Buffer Float[3]	Jan-20	City Center/Project Completion
0% - Earliest Date	Feb-19	10 months early
10% ile	Jul-19	6 months early
25% ile	Sep-19	3 months early
50% ile	Oct-19	2 months early
80% ile	Jan-20	On Target
90% ile	Feb-20	1 month late
100% ile - latest date	Apr-21	16 months late

1. Date based on RTD's Integrated Project Schedule (IPS) dated December 10th 2010.
2. Includes 4 months end float from current RTD IPS Revenue Commencement Date (RCD).
3. Date includes 16 months float on critical path of stripped schedule.

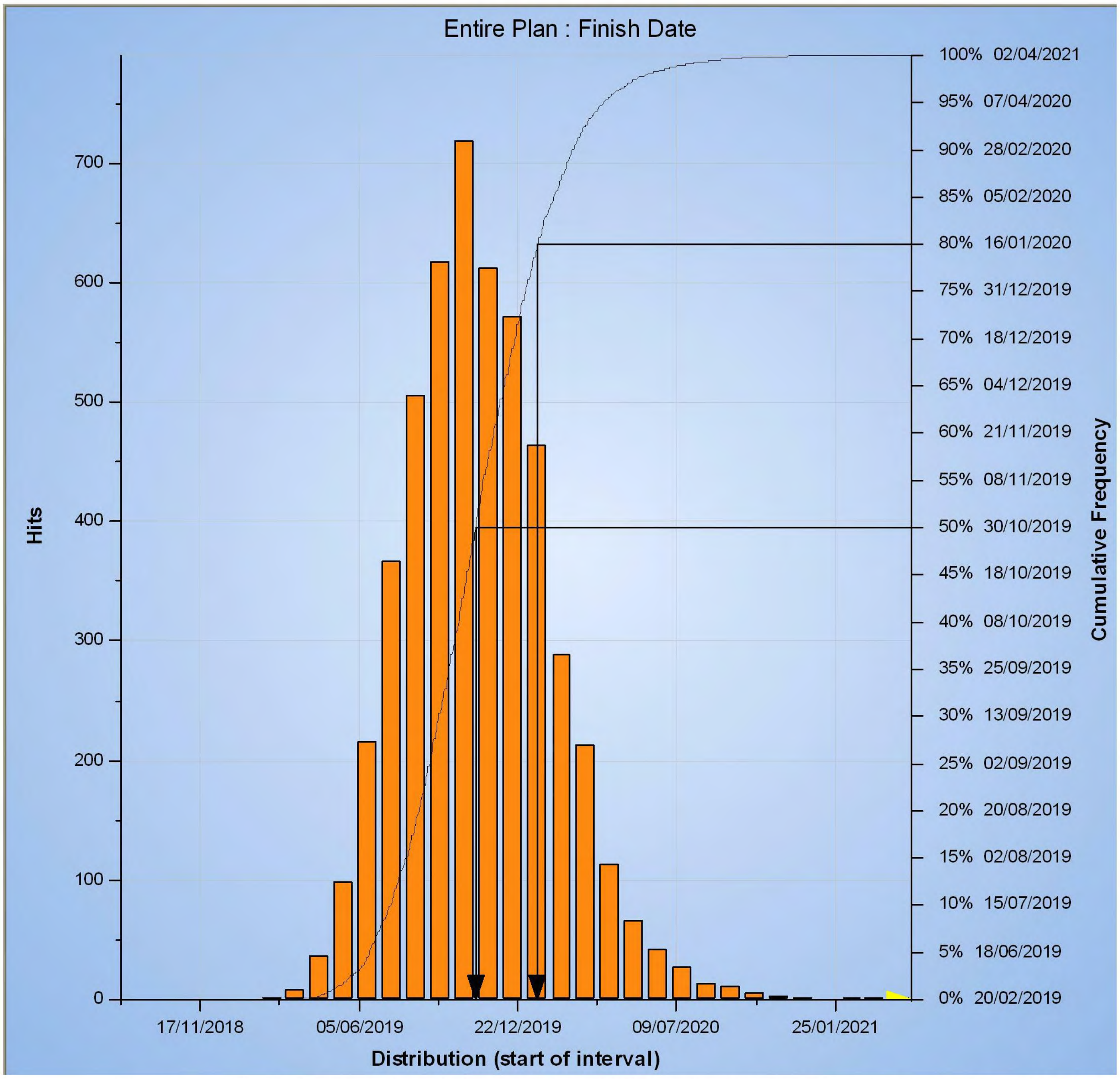

Figure 1-2. Schedule Risk Analysis—Whole Project Completion (City Center)

1.4 Recommendations for Secondary Risk Mitigation

To mitigate the potential greatest cost and/or schedule risks to the Project, PB recommends the following mitigation measures:

To be discussed

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2 Project Details

2.1 Project Status

The Project is currently working toward approval to commence Final Design in the second quarter of 2011 following the anticipated signing of the ROD in January 2011.

2.2 Project Description

The project alignment was studied for potential risks and assessed as to the required schedule and cost contingency requirements. The Project is a light rail transit starter project for the City and consists of 20 miles of elevated light rail guideway extending from East Kapolei to Ala Moana Center.

The Project consists of 105,880 route feet of elevated guideway, 20 elevated stations, 1 at-grade station, a maintenance and storage facility (MSF) and service yard, parking facilities, intermodal facilities, utilities, roadway improvements, all systems work, right-of-way (ROW) acquisition, relocations, 76 rail cars, and complete professional services, including design, construction management, and owner costs. The Project is divided into multiple contracts as described in Table 2-1. The project alignment is shown in Figure 2-1.

The alignment is divided into the following four Sections:

- **West O‘ahu/Farrington Highway Section**—6.86 miles (Sta.392+00.00 to Sta.754+30.13)
- **Kamehameha Highway Section**—3.88 miles (Sta.770+00.00 to Sta.974+94.16)
- **Airport Section** —5.17 miles (Sta.988+60.43 to Sta.1274+39.25)
- **City Center Section** —4.45 miles (Sta.1274+39.25 to Sta.1358+58.37)

The 21 stations are divided by Section as follows:

- The WOFH Section includes six stations:
  - East Kapolei Station
  - UH West O‘ahu Station
  - Ho‘opili Station
  - West Loch Station
  - Waipahu Transit Center Station
  - Leeward Community College Station
- The Kamehameha Highway Section includes three stations:
  - Pearlridge Station

- Aloha Stadium Station
  - Pearl Highlands Station
- The Airport Section includes four stations:
  - Pearl Harbor Naval Base Station
  - Honolulu International Airport Station
  - Lagoon Drive Station
  - Middle Street Transit Center Station
- The City Center Section includes eight stations:
  - Kalihi Station
  - Kapālama Station
  - Iwilei Station
  - Chinatown Station
  - Downtown Station
  - Civic Center Station
  - Kaka'ako Station
  - Ala Moana Center Station

Table 2-1. List of Contract Packages

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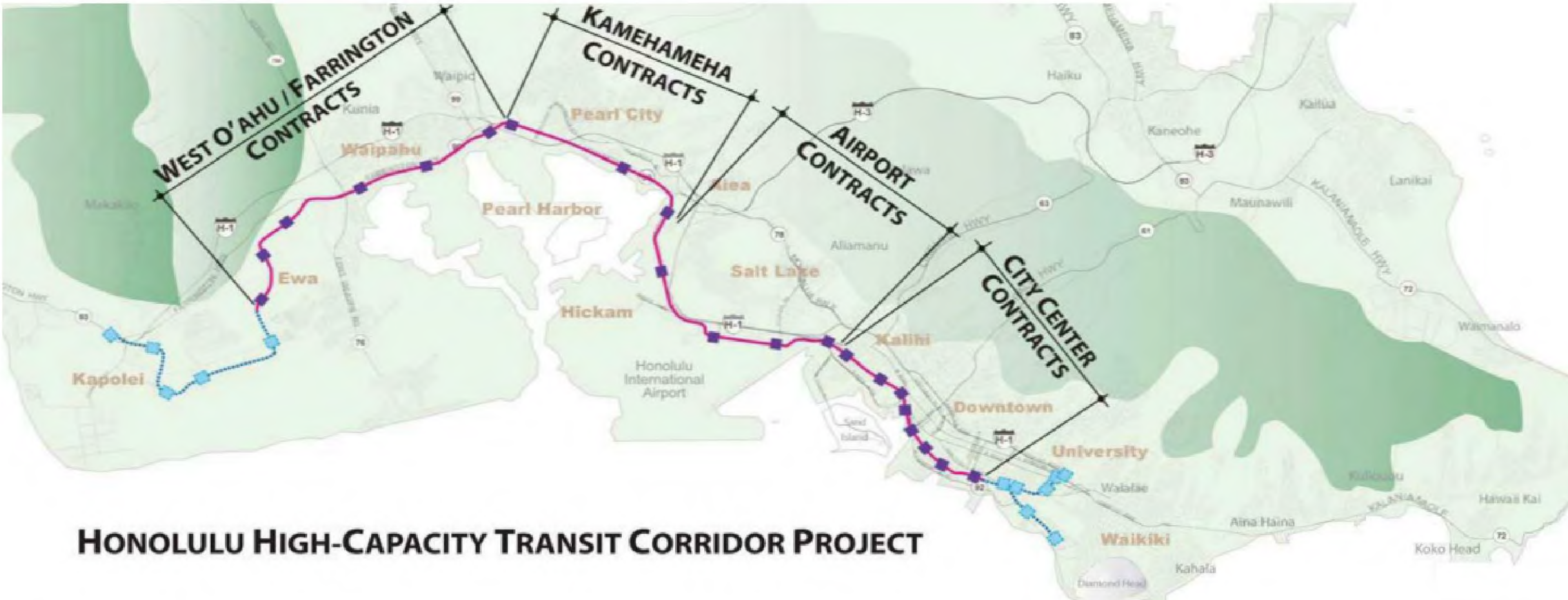

CONTRACT PACKAGING SITE MAP

West O'ahu / Farrington Contracts	Kamehameha Contracts	Airport Contracts	City Center Contracts	Project Wide Contracts
FD140 W. Oahu Stations (3) Design FD240 Farrington Stations (3) Design DB120 W. Oahu / Farrington Guideway DB DB200 Maintenance & Storage Facility DB DBB170 W. Oahu Stations (3) Construct DBB270 Farrington Stations (3) Construct MM180 W. Oahu/Farrington Station CE&I	FD340 Kamehameha Hwy Stations (3) Design FD245 Pearl Highlands Garage & Ramps Design DB320 Kamehameha Hwy Guideway DB DBB370 Kamehameha Stations (3) Construct DBB275 Pearl Highlands Garage & Ramps Constr MM380 Pearl H'lands & Kamehameha Stations CE&I MM385 Pearl H'lands Garage & Ramps CE&I	FD430 Airport Utility & Guideway Design FD440 Airport Stations (3) Design DBB450 Airport Utility Relocation DBB460 Airport Guideway Construct DBB470 Airport Stations (3) Construct MM480 Airport Utility & Guideway CE&I MM485 Airport & Dillingham Stations CE&I	FD530 City Center Utility,Guideway and Ala Moana Station Design FD540 Dillingham Stations (3) Design FD542 City Center Stations (3) Design FD545 Kaka'ako Stations (2) Design DBB550 City Center Utility Relocation DBB560 City Center Guideway Construct DBB570 Dillingham Stations (3) Construct DBB572 City Center Stations (3) Construct DBB575 Kaka'ako Stations (2) Construct MM580 City Center Utility & Guideway CE&I MM585 City Center & Kaka'ako Stations CE&I	MM900 Program Management Support Consultant MM905 General Engineering Consultant (EIS/PE) MM910 General Engineering Consultant (Final Design & Construction) MM915 HDOT Traffic Mgmt Coord Consultant MM920 HDOT Design/Constr Coord Consultant MM930 HDOT State Oversight Agency (SOA) MM935 Real Estate Consultant DBOM920 Core Systems DBOM MI930 Project Wide Elevators & Escalators OF950 Owner Furnished Plants & Shrubs

Contract Coding :

FD Final Design Contracts
DB Design-Build Contracts
DBB Design-Bid-Build Construction Contracts
DBOM Design-Build-Operate and Maintain Contract
MM Management Contracts
MI Manufacture + Install Contracts
OF Owner Furnished Contracts

Contract numbers typically 3 digits
First digit indicates location:
1xx West Oahu
2xx Farrington
3xx Kamehameha
4xx Airport
5xx City Center
9xx Project Wide

Second digit indicates category:
x2x Design Build
x3x Design Utility & Guideway
x4x Station Design
x5x Utility Relocation
x6x Guideway Construction
x7x Station Construction
x8x Construction, Engineerig & Inspection
Second digit rule does not apply to 9xx series.

Figure 2-1. Project Alignment Map

2.3 Project Budget

The project budget at YOE, excluding finance costs, is $5.167 billion, as summarized in Table 2-2.

Table 2-2. Summary of Budget Cost Estimate at Year of Expenditure

Contract Packages	Estimate With Contingency (YOE)
West O'ahu/Farrington Highway Guideway	555,362,600
Maintenance and Storage Facility	213,997,624
Kamehameha Guideway	354,239,046
West O'ahu/Farrington Highway Stations	365,680,086
Kamehameha Highway Stations	72,777,247
Airport Guideway	460,766,644
Airport Stations	52,255,441
City Center Guideway	504,139,027
City Center Stations	204,114,577
Systems	886,211,241
Elevators and Escalators	77,380,231
Utilities by Utility Companies	147,957,423
Right of Way	243,287,411
Owner Furnished Plants and Shrubs	7,923,194
Final Design	112,234,570
City and County of Honolulu	193,927,237
CE&I	94,021,693
PM	421,665,802
Total	**4,967,941,092**
Unallocated Contingency	$198,717,644
Total with Unallocated Contingency	**$5,166,658,736**

2.4 Project Schedule

The risk assessment is based on the RTD project schedule as of December 10, 2010. Key dates in the project schedule are summarized in Table 2-3.

Table 2-3. Summary of RTD Project Key Dates

Milestones	RTD Schedule (As of December 10, 2010)
Record of Decision	19-Jan-11
Commence property acquisition	19-Jan-11
Commence WOFH utility relocations	10-May-11
FTA approval to enter Final Design	19-Jul-11
NTP#4 WOFH - Commence main construction	21-Jul-11
FTA issue FFGA	2-Oct-12
100% Bid (assumes 12 months after FFGA)	2-Oct-13
20% Constuction	1-Apr-12
50% Construction	1-Apr-14
75% Construction	1-Jan-16
90% Construction	1-Jul-17
Sectional Completion Dates (before end float)	
Opening #1 - WOFH, MSF and KHG	30-Dec-15
Opening #2 - Airport	3-Oct-17
Opening #3 -City Center	31-Mar-19
Project Completion	
RTD (cash flow target) Revenue Commencement Date	31-Mar-19

The RTD project schedule assumes that construction of the Pearl Highlands Station parking garage, the Airport and City Center guideway, and associated stations and core systems occur after the Full Funding Grant Agreement (FFGA) is in place (albeit the core systems contract as a whole is awarded prior to the FFGA under a LONP).

The RTD project schedule assumes formal approval to enter Final Design is required prior to award of construction contracts for any stations. The schedule assumes Final Design can be progressed under advanced Preliminary Engineering (PE) to allow for bidding of construction contracts for the guideway and stations, but contract award cannot occur unless an LONP is granted. The schedule also assumes approval to enter Final Design must be obtained and that the normal FTA application, review, submission, and approval process is followed for the FFGA.

The RTD project schedule assumes LONPs will be obtained and granted by FTA after approval to enter Final Design to permit construction activities to be commenced in advance of a FFGA.

The RTD project schedule does not identify any specific constraints in working hours, access, critical utility seasonal outages, special events, or the like. Production durations are generally based upon a five-day work week with limited nighttime work in compliance with the measures established in the environmental impact statement. Extended working hours are assumed for utility relocations and casting of deep column casings limited only by local agreements with the Hawai‘i Department of Transportation, Highways Division. The RTD project schedule assumes an amicable and partnering relationship ensues with both public and private utility companies and that the Hawai‘i Department of Transportation, Highways Division continues its historic pro-active working relationship with the City and its contractors in achieving a successful project not obstructed by unreasonable limitations or working constraints.

3 Characterization of Project Scope, Cost, Schedule, Technical Capacity, and Capability

3.1 Introduction

During the risk analysis process the baseline assumptions for the Project were established. The summary of the project scope, cost, and schedule are as described in Section 2 and were presented by the design team as part of the general introductions to the Project and then elaborated upon as the risk analysis process progressed. This section provides the most current project details that were available for the identification and quantification of risk. Workshop and meeting discussions, summary of scope, and the identified risks are provided in Section 4.

3.2 Line Capacity

The required capacity of the Project in respect to peak-hour passenger loading, frequency of trains, travel distance between stations, and dwell times have been established and form part of the Core Systems performance specification currently in the final stages of a process of BAFO with short-listed bidders. The resulting bid will form the basis of a contract to design, manufacture, install, operate, and maintain a transit service for an initial period of five years, with options to extend from date of first operation of the completed total alignment (City Center).

Although the risk assessment team has not been privy to confidential bid submission information, it is believed that following bid award, risk is limited to those issues identified in the risk register, primarily those related to approval and construction. A number of requirement risks have been identified in the risk register. Some of those identified will form “bid options” to be considered by the City subject to availability of funds. No requirement risks have been identified with respect to number of vehicles, number of stations, size or capacity of the MSF facility, or operational control in so far as they would impact the submission and awarded Core Systems Contract.

3.3 Technical Capacity and Capability

The City is currently supported by InfraConsult in program management for the Project through completion of PE and Final Design. The General Engineering Contract for the Final Design and construction phase (GEC2) is currently under negotiation. Plans are in place to support any shortfall in key City positions and to supplement City resources with consultant staff as required given the challenges with employment of medium and long-term direct City staff.

The Project Management Plan sets out the organization and process appropriately detailed for progression of Final Design and, where approved, for construction. The estimate is based upon a detailed staffing plan for each project phase clearly indicating full-time equivalents under each staffing category (FTA SCC 80) developed from the Project Management Plan. A parametric analysis was conducted to support the risk assessment to validate the cost estimate and staffing allowances (Table 3-1).

The comparative analysis shows the current estimate provisions for SCC 80 are very much in line with other New Starts projects. The notable variance is in Final Design costs; however, a significant portion of these costs are associated with design/build and design/build/operate/maintain procurement, which generally can be obtained at less cost than under traditional design/bid/build procurement. Provision in the risk assessment and adjusted stripped cost estimate has been made, however, for the possibility of increased Final Design costs above estimate allowances.

The City and RTD have implemented the Oracle CMS project management system and are currently populating the system, training staff in its operation and reporting capabilities, and implementing the system with the appointed contractors for the WOFH and MSF Contracts. It is the intention that this world-class system be adopted to manage documentation, control and report schedule and costs, manage changes and submittals, and interface with the payments system by rolling up percent completion on each contract package. Challenges remain with its implementation; however, system implementation is progressing and is on schedule to support main construction and resolve any problems during the current early phases.

Table 3-1. Parametric Analysis of Costs of SCC 80 in Comparable New Start Projects

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3.4 NEPA

No unusual significant constraints or undertakings have been identified arising out of the environmental process.

Provision has been made in the adjusted stripped cost estimate and through the risk assessment for issues in connection with location of precast segmental casting yard facilities.

The possibility of discovering and dealing with iwi is extensively documented in the risk register, and allowances have been made in both the cost and schedule risk assessments. A focused risk mitigation action plan is in place for development of a formal approach to dealing with iwi.

Possible impacts in mitigation of risk to historic structures, removal of contaminated material, and crossing water courses have been documented throughout the risk register and provision has been made within the estimate and risk assessment.

3.5 NFPA130 Fire Life Safety

Means of escape in the event of a train failure or accident on the guideway, additional passenger emergency access, guideway walkways, guideway lighting, platform edge doors, elevator numbers at stations, bus stops, and associated passenger access and egress from stations have all been discussed in detail and are documented throughout the risk register with provision made within the estimate and risk assessment where appropriate.

3.6 Contract Packaging Plan

The contracting strategy has been designed to take full advantage of the prevailing very favorable bidding market conditions, low escalation and interest rates, and abundance of the best quality management and supervisory staff.

The segmental approach to guideway and station construction has been developed to facilitate the possible sharing of casting yard facilities, transition of specialist foundation and erection equipment from one Section to another, and best use of local labor being trained on the earlier Sections to provide potentially increased productivity and lower incidence of quality issues on latter Sections. These and other similar strategies recognize the island location and constraints this project imposes on material and equipment deliveries, labor availability, and the cost of labor temporarily assigned to the Project from the mainland. The estimate is perceived to be conservative in its recognition of these very significant potential economies of scale and learning curves that will manifest themselves on this project.

The contract strategy recognizes the potential significant delays that could result by not relocating the existing utilities ahead of the guideway and station foundation contracts. This risk is significantly reduced by the separation of the bulk of utility relocations in the Airport and City Center Sections into earlier advance contracts separate from the main guideway and stations contracts. These contracts are as follows:

- DBB450—Airport Section Utility Relocations
- DBB550—City Center Section Utility Relocations

The guideway is proposed to be constructed in four Sections. The WOFH Section is already awarded and is awaiting the ROD to progress casting yard fabrication and foundation construction. The Kamehameha Section is the subject of a BAFO in an attempt to identify additional savings. Both contracts are based upon the design/build approach. The Airport and City Center guideway contracts are currently proposed as design/bid/build; however, with the delays in the ROD and the possibility of further delays in approval of LONPs there is a possibility of an accelerated design/bid/build or a design/build procurement being considered for one or both of these contracts. This option provides possible risk mitigation in design and schedule overages and also manages the potential shortage of bidders driven by the casting yard advantage that the initial two contracts provide successful bidders over subsequent new entrants to the Project. The guideway contracts are as follows:

- DB120—West O'ahu Farrington Highway Guideway—Design/Build
- DB320—Kamehameha Guideway Contract—Design/Build
- DBB460—Airport Guideway
- DBB560—City Center Guideway and Ala Moana Center Station

Contract DB200-MSF Contract, Design/Build, has been awarded to Kiewit under a design/build contract. Potential risk exists for changes in layout and scope to accommodate the selected Core Systems contract as the MSF supplies rail, fastenings, constructs buildings, lays out the storage yard and maintenance facility, and provides equipment to be tested and operated by the Core Systems contractor. The procurement of the facilities ahead of the operator has maximized the prevailing favorable market conditions, reducing the risk of inflation and providing the opportunity for an early start once the ROD has been signed and an LONP has been obtained for progressing the earthwork to re-grade and level the site and order rail and other materials.

The strategy for individual contracts has been to size them to specifically target the local market and to make the contracts fall within the bonding capacity of medium-sized contractors. The use of local labor will achieve the most competitive prices while supporting the local economy and satisfying the public commitments made for the economic re-generation of local businesses from the Project. Staggered bidding will permit maximum competition while also allowing earlier successful contractors to competitively bid latter contracts on other Sections using lessons learned and economies that can be derived from earlier contracts. The proposed station contracts are as follows:

- DBB170—West O'ahu Stations (3)
- DBB270—Farrington Stations (3)

- DBB275—Pearl Highlands Garage and H-2 Ramps
- DBB370—Kamehameha Highway Stations (3)
- DBB470—Airport Stations (3)
- DBB570—Dillingham Stations (3)
- DBB572—City Center Stations (3)
- DBB575—Kaka‘ako Stations (3)

DBOM920—Core Systems, DBOM—The strategy of a design/build/operate/maintain approach to the Core Systems, which incorporates vehicle procurement, is likely to reduce claims that might otherwise arise within the Core Systems scope from interfaces, particularly in testing and start-up. It is recognized that the greatest area of risk to the Core Systems Contract is likely to be in the late handover of civil's access on guideway and at stations for Core Systems installations. The number of separate station packages will be particularly challenging to coordinate and whereas multiple faces may be available for construction, claims can be anticipated if the Core Systems contractor is forced into mobilizing additional teams for systems installation and associated plant and equipment that would, in an ideal scenario, follow on from one station to the next.

Ten station design contracts are proposed. The schedule assumes a staggered approach to bid and award to allow for the maximum participation in any bid (i.e., failed bidders from one bid request can submit on subsequent bid requests). This should provide the best pricing for the City while allowing for the maximum participation of local design companies. The currently proposed design contracts are as follows:

- FD140—West O‘ahu Stations Design
- FD240—Farrington Highway Stations Design
- FD245—Pearl Highlands Garage and H-2 Ramps Design
- FD340—Kamehameha Stations Design
- FD430—Airport Section Utility and Guideway Design
- FD440—Airport Stations Design
- FD530—City Center Section Utility, Guideway, and Ala Moana Station Structure Design (Ala Moana Station Finishes are part of FD545)
- FD540—Dillingham Stations Design
- FD542—City Center Stations Design
- FD545—Kaka‘ako Stations Design

One contract has been currently proposed for the Elevators and Escalators (MI930—Elevators & Escalators Procurement, Install & Test). There is also discussion of incorporating a long-term maintenance contract as part of the initial supply and installation contract. On other projects this has resulted in significant savings driven by the long-term revenue stream offered. For this project, it would also provide the ability to establish permanent local resources that would benefit the City, the operator, and the contractor, as well as supporting the local economy and labor force. Opportunity for savings could be realized in alternative approaches to procurement that incorporate maintenance, similar to the Core Systems contracting approach.

There are seven currently identified CE&I contracts. These contracts also have the objective to maximize opportunities for smaller and medium-sized companies to be competitive and engaged by using local labor to reduce costs when compared to using mainland resources. The proposed contract packages are as follows:

- MM180—West O‘ahu Stations CE&I
- MM380—Pearl Highlands Station and Kamehameha Stations CE&I
- MM385—Pearl Highlands Garage & H2 Ramps CE&I
- MM480—Airport Section Utility and Guideway CE&I
- MM485—Airport and Dillingham Stations CE&I
- MM580—City Center Utility and Guideway CE&I
- MM585—City Center and Kaka‘ako Stations CE&I

3.7 Scope Baseline

See Section 2.2 for the current project scope and project alignment map.

3.8 Cost Baseline

A summary of the project cost is provided in Section 2. Refer to the Basis of Estimate Report dated October 14, 2010, for a complete report of the process used to produce the estimate. For the cost risk analysis, the estimate has been stripped and then adjusted to reflect identified errors, omissions, and additions as described in Section 5. The following is a more detailed summary of the estimate.

3.8.1 General

- The estimate was prepared following FTA Standard Cost Category (SCC) format using 2010 dollars and including varying levels of contingency and general excise tax.
- The estimate was developed using Timberline software, a database-driven program used for cost estimating.
- A custom-tailored approach was used in this estimate as select design/build projects have been awarded, or are in award negotiation, with the remaining being in the PE phase.

- Labor rate tables were developed using the current Hawai‘i prevailing wage rates.
- Material costs used were in 2010 second-quarter dollars.
- Equipment costs were based on vendor quotations and industry standard publications.
- Quantities were taken off independently by design subconsultants and estimators, then compared and reconciled. Reconciled quantities were then used for estimating purposes.
- The estimating program contains a detailed, crew-based database for labor, materials, and equipment. The database also contains production rates for the crews assigned to the tasks associated with the item. Most item production rates were adjusted to reflect the specific project working conditions.
- In various cases, a waste factor was incorporated to the material quantities to accurately reflect construction practices.
- Contingency was allocated in varying amounts to each contract package and SCC code. As outlined below for each SCC code based on “known unknowns” and at the total project level, unallocated contingency was used to address “unknown unknowns” based on a percentage add-on of 4 percent.

3.8.2 *Allocated Contingency by Contract Package*

For each contract package, the BCE contains the average percentage allowances shown in Table 3-2 for allocated contingency.

Table 3-2. Allocated Contingency by Contract Package

Contract Packages	% Allocated Contingency
West O'ahu/Farrington Highway Guideway	15%
Maintenance and Storage Facility	9%
Kamehameha Guideway	20%
West O'ahu/Farrington Highway Stations	20%
Kamehameha Highway Stations	20%
Airport Guideway	21%
Airport Stations	21%
City Center Guideway	21%
City Center Stations	20%
Systems	15%
Elevators and Escalators	20%
Utilities by Utility Companies	26%
Right of Way	40%
Owner Furnished Plants and Shrubs	20%
Final Design	10%
City and County of Honolulu	10%
CE&I	10%
PM	9%
Project Average Allocated Contingency	**17%**
Unallocated Contingency	4%
Average with Unallocated Contingency	**22%**

3.8.3 SCC Codes 10 through 50 (Construction)

The BCE contains the average percentage allowances shown in Table 3-3 for allocated contingency.

Table 3-3. Allocated Contingency for SCC Codes 10 through 50

Standard Cost Category Major		Allocated Contingency
10	Guideway and Track Elements	18%
20	Stations, Stops, Terminals, Intermodal	20%
30	Support Facilities: Yards, Shops, Admin. Bldgs.	10%
40	Sitework & Special Conditions	21%
50	Systems	20%
60	ROW, Land, Existing Improvements	40%
70	Vehicles	10%
80	Professional Services	11%
90	Unallocated Contingency	4%
Average Project Wide Contingency		**22%**

3.8.4 SCC 60 ROW Acquisition Costs

The SCC 60.01 and 60.02 estimate includes relocations, goodwill, legal fees, and damages, as follows:

- $235.4 million (BCE 2010)
- $243.3 million (BCE YOE)

The above figures include a 40 percent contingency allocated to SCC 60 ROW.

A summary of discussions and interviews with RTD ROW staff held in September 2010 is included in Section 4, which also provides a more detailed background to the current estimate of property acquisition and associated costs.

3.8.5 SCC 70 Vehicles

SCC 70 is comprised of the following:

- 76 passenger vehicles—approximately 60 feet in length
- Other core systems

AR00088281

- Special equipment
  - 10 maintenance-of-way vehicles
  - 18 road vehicles
- 5 percent contingency allocated to SCC 70 vehicles

3.8.6 SCC 80 Soft Costs/Design/Management

Project soft costs were developed based on a staffing approach. PB, in cooperation with major stakeholders, developed a staffing matrix for all major categories of soft costs. In addition:

- The general excise tax was applied to all lump-sum contracts and cost-plus contracts.
- GET was not applied to City staff or ROW procurement.
- An allocated contingency of 10 percent was applied to each soft cost category line item.
- When calculated, all Category 80 costs are about 33 percent of Categories 10 through 50 construction costs.

3.8.7 SCC 90 Unallocated Contingency

An unallocated contingency of 4 percent has been established as a reserve of capital to carry the potential cost overruns for the program.

3.9 Schedule Baseline

The schedule is based upon the draft contract packaging plan as described above. The project schedule is as described in Section 2. Refer to the Basis of Schedule dated December 10, 2010, for a further description of the process used in producing the schedule.

4 Risk Identification and Assessment

4.1 Preface

This section describes the process used for identification and quantification of risks to the Project. This process, as comprehensive as it has been given the current status of the design, is unlikely to have identified all possible risks. The identification of risks will continue as the Project develops through the various stages of project delivery. Experience from other similar transit projects has been used in the quantification of risk, in making allowance for those risks that may occur that have not as yet been specifically identified on the risk register, and in arriving at conceivable maximum ranges of cost and schedule impact given the lessons learned from past projects. The objective is to place RTD in a position whereby the risk process assists in more informed decision making with respect to procurement strategy and provision of cost and schedule contingency capacity. In addition, the intention is to provide FTA with confidence RTD has made a significant effort to identify, quantify, and mitigate risks to this project and have allowed reasonable provision for contingency sufficient to see the project to a successful on time and on budget revenue operations.

4.2 Methodology for Identification and Ranking of Risks

An initial risk register was developed for the Project in September 2008 prior to entry into PE. The FTA/PMOC then prepared a separate risk register and analysis during their review at the Project's application to enter PE. The FTA/PMOC risk assessment spot report was published in July 2009. The risk registers at this stage were not scored for likelihood or impact.

During PE, a more comprehensive and detailed risk register was developed. The Project Team has reviewed the pre-PE risk register and the FTA/PMOC spot report. Meetings were held in April 2010 with the design team where the existing identified risks were reviewed. If these risks were no longer relevant, they were removed from the risk register and new risks were added. The risk register was reviewed again in June 2010 with a further round of small workshops with the design team. The risks contained in the updated risk register were then coded to the FTA standard cost categories, given a "risk type" and "risk group" code to aid sorting and reporting, and coded to their most relevant project geographical Section. At this stage, no quantification of the risk register was undertaken.

During September 2010 a further review was conducted of the risk register and involved more detailed risk review meetings with both the design and project management teams, including key RTD senior management. Risks on the risk register were scored for likelihood of occurrence and potential impact to the project cost and schedule if they should occur. The scoring matrix, which was agreed upon with RTD, is provided in Table 4-1. A listing of the risk review sessions conducted in September 2010, along with attendees at each session, is provided in Appendix A.

The current risk register is incorporated as Appendix B. This risk register will be used as a basis for the schedule and cost risk models and also as a project risk tracking tool throughout the entirety of the Project.

Once an agreed-upon risk register was produced, a separate meeting was held with the PMOC team on November 2 and 3, 2010. The list of attendees during the PMOC over-the-shoulder review in November is provided in Appendix A3. The PMOC was provided with the draft risk register at that time and has been asked to provide additional comments and suggestions. The matrix shown in Table 4-1 is a means to score and rank the identified risks.

Table 4-1. Risk Matrix

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Risks were assessed as to the following:

- Likelihood of occurrence
- Potential (and most likely) cost impact
- Potential (and most likely) schedule delay

The total score has been arrived at through adding the cost and time scores, dividing by 2, and then the result multiplied by the likelihood score. For example:

- Likelihood = 3
- Cost Impact = 4
- Schedule impact = 2
- Resulting score = 4+2 = 6 / 2 = 3 x 3 = 9 Medium Risk

4.3 Risk Identification Baseline

4.3.1 Workshop Attendees

A record of attendees for risk review sessions is provided in Appendices A1, A2, and A3.

4.3.2 Introduction and Presentation on Process

A short presentation on the FTA risk assessment process was provided, followed by a summary of the baseline scope to each risk review session. This presentation is provided in Appendix H.

4.3.3 Baseline Scope, Cost and Schedule

Refer to Sections 2 and 3 for a detailed description of the baseline scope, cost, and schedule, which were used to determine possible impacts to the Project and which were relevant to the identification and analysis of risks.

4.3.4 Updating the Project Risk Register

During the week of September 13, 2010, a series of risk identification meetings were held with the project design and management team and RTD. Each session began with an introduction to the overall risk assessment process and included the following disciplines:

- Structures
- ROW/Property Acquisitions
- Utilities
- Rail
- Core Systems
- Civil/Geotechnical
- Schedule and Cost Estimate/Project Controls
- Environment
- Safety and Security
- Contracts and Procurement
- Program-level Risks
- Station Architecture

Separate and specific risk review sessions were held with senior management from RTD and PB covering Core Systems, ROW, and procurement. A program-level risk identification session was also held with senior RTD and PB management. Theses series of review meetings were followed by a more detailed “walk” down the alignment focusing on potential hot spots in ROW, utilities, environmental, and stations to identify conflicts and more specific areas of potential risk.

The working sessions on September 22, 2010, focused on the scoring of risks identified in the now updated risk register covering all risks coded to SCCs 10 through 70. Three separate scoring sessions were held for utilities; environmental; and the remaining risks for stations, civil, and rail. To ensure an unbiased assessment of risk discussion as to likelihood and impact, sessions were first conducted with middle management involving design staff supported by their corresponding RTD lead. Cost and schedule project-controls staff were involved in all review meetings where risk quantification was discussed to ensure consistency and to avoid any duplication with the Project's estimate and schedule.

With the risk register now quantified by middle management as of September 23, 2010, a half-day workshop was convened where quantification of risks scored as "high" and risks assigned to SCC 80 and 90 were reviewed by PB and RTD senior management. During these discussions, the probability and cost and schedule impacts for some risks were adjusted and descriptions and consequences were further refined.

4.3.5 Value and Risk Targets

Participants of the RTD risk identification workshop agreed that the following areas of scope create the greatest cost and time uncertainty:

- Geotechnical
- Utilities
- Right-of-way
- Guideway Sections
- Stations

4.4 Identified Risks

4.4.1 Summary

During the risk identification process, 156 risks were identified and agreed upon as possible risks to the Project. A total of 19 high risks were identified, along with 73 medium risks and 64 low risks. The project risk register is provided in Appendix B.

Table 4-2 lists the top 10 risks to the Project.

Table 4-2. Top 10 Project Risks

Risk ID	SCC Code	Section	Risk Description
467	10.04	City Center	Given limited geotechnical information available at this time, additional costs may be incurred associated with differing subsurface conditions.
312	90.00	Core Systems Project Wide	City may require design changes to DB submittals resulting in formal change orders.
252	80.00	Project Wide	Soft costs - design, program, construction and Agency management may be under-estimated depending on schedule following ROD announcement.
270	80.06	Project Wide	Unanticipated litigation may add cost to the Project (e.g,.protests from adversary groups, community groups, adjacent landowners and other affected parties).
273	90.00	Project Wide	FTA review and approvals process may delay entry into Final design .
300	90.00	WOFH	Delay to issue NTP results in claims for additional costs.
473	80.00	Project Wide	Additional City staffing costs incurred due to establishment of Transit Authority.
191	40.08	City Center	Traffic disruptions in City Center Section may result in revised constraints imposed by City or HDOT (lane restrictions, peak time flow restrictions, etc.) .
389	40.02	City Center	State or Board of Water Supply may not grant waiver to leave in place existing utilities that are not impacted by new structures. Current plan is for utilities to be abandoned and change would require partial or total removal.
364	40.04	City Center	During excavation for new utilities iwi (archeological human remains) may be found which would require revised alignment (for utility relocations) if iwi are preserved in place.

4.4.2 *Analysis of Identified Risks*

During the risk identification process, 156 risks were identified and agreed upon as possible risks to the Project. Following risk identification, risks were scored against an agreed-upon matrix (Table 4-1) for likelihood of occurrence and potential cost and schedule impact to the Project should they occur. The project risk register is provided in Appendix B.

Based on the risk scoring matrix, 19 high risks were identified, along with 73 medium risks and 64 low risks.

Figure 4-1 shows the number of risks allocated by FTA SCC Level 1, and Table 4-3 shows risks by percentage to FTA SCC Level 2.

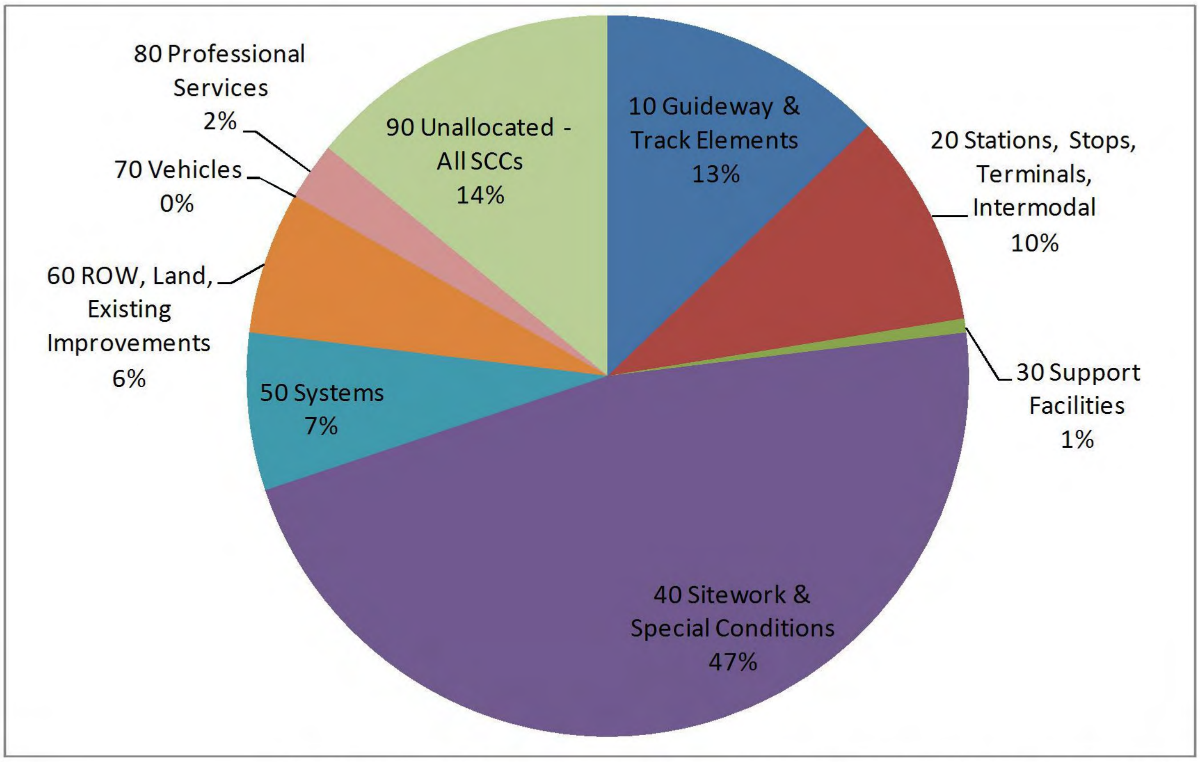

Figure 4-1. Allocation of Identified Risks to FTA SCC Level 1

Table 4-3. Allocation of Identified Risks to FTA SCC Level 2

SCC	Description	# Risks	%
10.04	Guideway: Aerial structure	15	9.62%
10.08	Guideway: Retained cut or fill	4	2.56%
10.09	Track: Direct fixation	1	0.64%
20.02	Aerial station, stop, shelter, mall, terminal, platform	14	8.97%
20.07	Elevators and escalators	1	0.64%
30.03	Heavy maintenance facility	1	0.64%
40.02	Site Utilities, Utility Relocation	40	25.64%
40.03	Hazmat, contaminated soil removal/mitigation, ground water treatments	5	3.21%
40.04	Environmental mitigation, e.g., wetlands, historic/archaeological, parks	21	13.46%
40.08	Temporary facilities and other indirect costs during construction	7	4.49%
50.01	Train control and signals	7	4.49%
50.02	Traffic signals and crossing protection	1	0.64%
50.03	Traction power supply: Substations	1	0.64%
50.06	Fare collection system and equipment	1	0.64%
50.07	Central control	1	0.64%
60.01	Purchase or lease of real estate	10	6.41%
80.00	Professional services general	2	1.28%
80.05	Professional liability and other non-constructioninsurance	1	0.64%
80.06	Legal; permits; review fees by other agencies, cities, etc.	1	0.64%
90.00	Unallocated - all SCCs	22	14.10%
Total		**156**	**100%**

Based on the most affected areas along the entire alignment, the 156 risks were assigned as either "Project Wide" or one of six specific Sections, as listed in Table 4-4.

Table 4-4. Percent of Identified Risks by Section

Contract	# Risks	%
Project Wide	49	31.41%
West O'ahu/Farrington Highway Section	34	21.79%
City Center Section	27	17.31%
Airport Section	17	10.90%
Kamehameha Highway Section	14	8.97%
Core Systems Project Wide	8	5.13%
Maintenance and Storage Facility	7	4.49%

The most risks were assigned to the "Project Wide" category, followed by the West O‘ahu Farrington Highway Section.

Further analysis was conducted to examine the particular risk types attracting the most risks for each risk severity level (high, medium, and low). The results are shown in Table 4-5. Civil, environmental, utility, and systems risks are most prominent (Figure 4-2).

Table 4-5. Identified Risks by Type and Severity

Risk Type Description	# of Risks				% of Risks Allocated		
	Total	High	Medium	Low	High	Medium	Low
Generic	26	6	12	8	32%	16%	13%
Civil	20	2	9	9	11%	12%	14%
Environmental	24	2	9	13	11%	12%	20%
Geotechnical	5	2	2	1	11%	3%	2%
ROW/Property	14	1	7	6	5%	10%	9%
Commercial	8	4	2	2	21%	3%	3%
Utilities	40	2	23	15	11%	32%	23%
Structural	7	0	1	6	0%	1%	9%
Systems and Vehicles	12	0	8	4	0%	11%	6%
Total	**156**	**19**	**73**	**64**	**100%**	**100%**	**100%**

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Figure 4-2. Allocation of Identified Risks to Risk Rating Types

4.4.3 Discussion on Risk Identification

This section summarizes the discussions on risks, categorized by SCC categories. Additional notes on individual risks are included in the risk register in Appendix B. In addition, the risk register records issues that are not considered to be risks or are covered by other issues.

SCC 10—Guideway and Track Elements

- Potential damage to existing streets and underlying utilities along haul routes (particularly in the City Center), and especially in areas associated with the large, heavy pre-cast concrete guideway sections, was discussed and deemed to be a risk to the Project.
- Access to construction sites and guideway erection locations for plant, equipment, and guideway sections was debated. No specific bridges or low-hanging overhead utilities were identified that might give rise to constraints unless avoided, raised, or relocated. In addition, limitations are unnecessary on plant, equipment, or unusual weight restrictions that could not be accommodated through the use of multiple-axle loaders.

SCC 20—Stations, Stops, and Terminals

- The Pearl Highlands Station and bus transit center are assumed to be constructed concurrently. Constructability issues that may otherwise occur are not considered a risk.
- Given the current level of design, the possibility exists that the station platform, entrance/exit, and circulation areas may increase in size from those currently shown on the station plans.
- There was considered no risk that the Airport would require RTD to provide additional infrastructure as part of this Project's funding. Any additional scope on top of that currently shown on the plans would need to be the subject of additional funding by the Airport.
- The baseline assumption is that additional entrances on Middle Street will not be covered in the project scope and, if required, would have to be funded by a developer separate from the Project.

SCC 30—Support Facilities: Yards, Shops, Administration Buildings

- Deformities in rail steel are considered not to be a risk. There was nothing usual about the specified profile.
- The configuration of the MSF is deemed not to be a risk since there is sufficient space for the number of vehicles proposed by current bidders.
- The current proposal for a fully automated storage yard has not been added to the scope. However, the change was not believed to result in any additional design changes and was not considered to impact cost.
- There are additional costs, although currently believed to be minimal, associated with the delayed Notice to Proceed for the MSF.

SCC 40—Site Work and Special Conditions

Utilities

- It was acknowledged that unforeseen military and Federal utilities may be encountered.
- Additional utility easements may be required due to both private and military utilities. Risks associated with these possibilities were added to the risk register.
- Where existing utilities are removed as opposed to left in place and abandoned there will likely be asbestos insulation associated with them. The removal of this insulation in place may cause schedule delay and prolonged disruption to traffic. Asbestos is most likely to be located in old electrical concrete street ducts.
- Utilities in the Center City Section are old and many are likely to be in poor condition. Connecting new pipe into existing manholes may require that the

complete existing host manhole be reconstructed. In addition, the extent of utility replacement to the closest joint of adequate strength, particularly for water and sewer lines, may also be a significantly greater distance than that included in the estimate.

- The electrical relocations originally to be carried out by the Hawaiian Electric Company (HECO) necessary for the WOFH Contract will now likely be undertaken directly by Kiewit as a change order, the value of which has yet to be agreed upon.

Risks associated with potential relocation of the existing 138 kilovolt (kV) HECO line(s) were acknowledged. The guideway alignment passes beneath 138kV and 46kV overhead lines at four locations:

- Near systems site 10
- In front of the HECO Waiau Substation
- At the west frontage of Aloha Stadium
- At the Intersection of Salt Lake Boulevard and Kamehameha Highway

Although the 46kV lines are planned for relocation, none of the 138kV lines are currently planned for relocation, and as such, no relocation costs for these high-voltage (138kV) lines are included in the cost estimate. The lowest 138kV conductor of the lines near systems site 10 is at an elevation of approximately 32.3 feet above the top of rail (TOR) at its maximum design sag. The three other elevations require maximum design sag calculations to be performed by a subconsultant to the Kamehameha contractor. The only information available at this time is the current elevations measured by surveyors using Light Detection and Ranging (LiDAR). The reason maximum design sag calculations need to be performed for the elevations of the lines is because elevations can change depending on the capacity of electricity in the line which, when increased, heats the cable materials and causes them to sag. HECO requires that these calculations be performed to verify that the minimum clearance elevation of 23 feet is met at all four locations. Per the LiDAR information:

- The lowest 138kV conductors of the line in front of the HECO Waiau Substation are at an elevation approximately 33 feet TOR.
- The lowest 138kV conductor of the line at the west frontage of Aloha Stadium is at an elevation approximately 41 feet above TOR.
- The lowest 138kV conductor of the line at the intersection of Salt Lake Boulevard and Kamehameha Highway is at an elevation approximately 34 feet above TOR.
- The 138kV cable raisings, potential diversions, and associated outages were discussed in detail with design managers; it was noted that only preliminary discussions have taken place with HECO to date. Several specific areas were discussed in detail with design managers as follows:
    - There would appear to be minor risk of significant costs on the KHG contract (five circuits at the Waiau substation area), should the

calculated design sag be much less than currently assumed as per LIDAR information. This is covered by Risk 119 and costs were suggested to range from $1 to $10 million depending on whether cables could be replaced with another material subject to less sag or undergrounding would be required and whether an outage would be possible without a separate temporary diversion.

- The wooden pole issue is covered under Risk 118 (also on the KHG contract) and concerns the necessary replacement of two guy-supported wooden poles with steel poles. An outage would be required to replace the poles and re-hang cable on the new poles. There would appear to be a minor risk that an outage might not be possible and a temporary diversion might be required to allow the line to be de-energized during pole replacement.

Risks 123 and 442 deal with the relocation of one side of the existing 138 kV cables (three poles and neutral) along Dillingham Boulevard for approximately 2,000 feet to 10 feet closer to the relocated sidewalk on new steel pylons. The other possibility is relocation to the underside of the guideway with terminations/risers that would require under street man ducts, entry/exit manholes, termination poles, etc. One or the other option will be carried out, but not both. However, there is a risk that in either case the relocation will not be possible without a temporary diversion given the outage required to safely relocate the poles and/or place the cables on the guideway. The options for a temporary diversion appear limited and potentially extremely costly. The City's preference is to attach the cables to the guideway, but this may not be acceptable to the Core Systems contractor. The current location of the 138kV poles would make maintenance impossible once the guideway is constructed. There is also an outage window and constraint issue given that access for annual maintenance is required and the relocation would have to be performed with this in mind, taking into account the fact that guideway construction would block access once built. The cost of relocation of the utility to the guideway structure is covered under Risk 442 and is included under the City Center guideway. The cost of the potential temporary relocation is covered under Risk 123 and is also included under the City Center guideway. No temporary diversion is included in the current estimate, and any additional costs associated with the relocation of cables to the underside of the guideway over that cost that would be incurred in relocation to the sidewalk are agreed to be reimbursed to the City by HECO. (Please refer to Appendix I for maps showing locations of 138kv conflicts.)

Environmental

- The discovery of iwi is deemed to be a high possibility, particularly in the City Center Section. The approach for dealing with iwi is addressed in the Programmatic Agreement. Considerable schedule delays however are possible should a mass burial ground be uncovered during excavation for utility relocations or main construction.
- The Federal Emergency Management Agency is in the process of revising its floodplain maps (to be complete in 2011), which could affect the Project and

require changes to the design. However, it is believed that any such effect would be small.

Geotechnical

A discussion of potential risks arising from unforeseen and/or differing subsurface conditions was held with the geotechnical engineering group. A review was undertaken of geotechnical risks and exposure to claims that followed the alignment from west to east and beginning with the WOFH Contract. The following sections summarize the key issues identified.

WOFH Sections B and C — under Contract to Kiewit through a Design/Build Contract

- Approximately 70 percent of the geotechnical investigations have been completed as of mid-October 2010. Based on the GEC's observations of the investigations to date, there is no indication of significant variations in subsurface conditions compared with conditions baselined in the *Geotechnical Baseline Report* (GBR).
- The GBR characterized soil conditions stratigraphically and baselined soils' engineering properties and groundwater levels, including artesian conditions, over the length of the guideway alignment. The GBR is specific to only the aerial guideway design and construction; it excludes at-grade civil structures and improvements. Perched groundwater is not baselined and poses a relatively nominal risk since it is a localized occurrence and dependent upon up-gradient precipitation or watering.
- In general, excavations that extend below the water table, both with and without artesian conditions, are required to be performed using wet construction. In the wet construction method, the level of slurry within the excavation is maintained above the water level in the surrounding soil to mitigating potential instability of the excavation and shaft. Slurry is principally clean water with or without natural or polymeric additives to enhance its stabilizing effects on the excavation. The contract stipulates that only clean water or polymer-modified slurry may be used for drilled shafts constructed in the wet. The contractor has stated that they intend to use only clean water as the drilling slurry. Because of concerns regarding the Southern O'ahu Basal Aquifer, the contract specification requires EPA approval if bentonite slurry is used. Post-treatment of the drilling slurry (such as that provided by the Baker tank system shown in Figure 4-3) is required to achieve regulatory standards prior to discharge.
- The risk associated with constructing drilled shaft(s) through perched water is nominal since it would be mitigated by installation of temporary casing to seal off the perched zone or, at worst case, using the wet construction method. This risk falls to the City. The risks associated with perched water are principally associated with the section of the alignment west of Kunia Road. The farmland here has groundwater that has been baselined at depths in

excess of 50 feet, which is below the Kiewit bid basis completion depths. East of Kunia Road the majority of the drilled shafts are planned for completion below the baselined groundwater level and therefore require wet construction.

- Hazardous materials are not baselined in the GBR. Per the contract, the City is responsible for the additional costs associated with management and disposal of any encountered contaminated materials. An old Army fuel line runs down a portion of Farrington Highway and there is evidence of petroleum contamination (at barely discernible levels) possibly associated with historic leakage of the line that was observed in several of the completed geotechnical borings that suggest near-surface contamination. Drilled shafts through the area of greatest potential risk will generally be constructed using temporary or permanent casing. Casing will limit the potential for uncontrolled cross-contamination during excavation. For reference, waste characterization studies on spoils from the geotechnical investigations indicated the level of contamination was above threshold levels, meaning that cuttings had to be disposed of at a regulated facility at a nominal additional cost. However, the levels do not approach that which would necessitate the materials being classified as hazardous waste. The risk from contaminated materials is principally associated with the portion of the alignment between Kunia Road and Waipahu High School.
- Excavation of utility trenches, which are typically limited to the upper 5 to 10 feet of the ground surface, are more likely to encounter petroleum-type contaminants at concentrations above regulatory action levels. Such a situation would require that the materials be managed and disposed of in a facility designated for such “non-clean” materials. Kiewit’s bid is based on a so-called clean environment, and the City is exposed to all extra costs associated with management, treatment, and disposal of construction-related contaminated or hazardous waste materials. This is a risk/cost associated with utility trench construction.

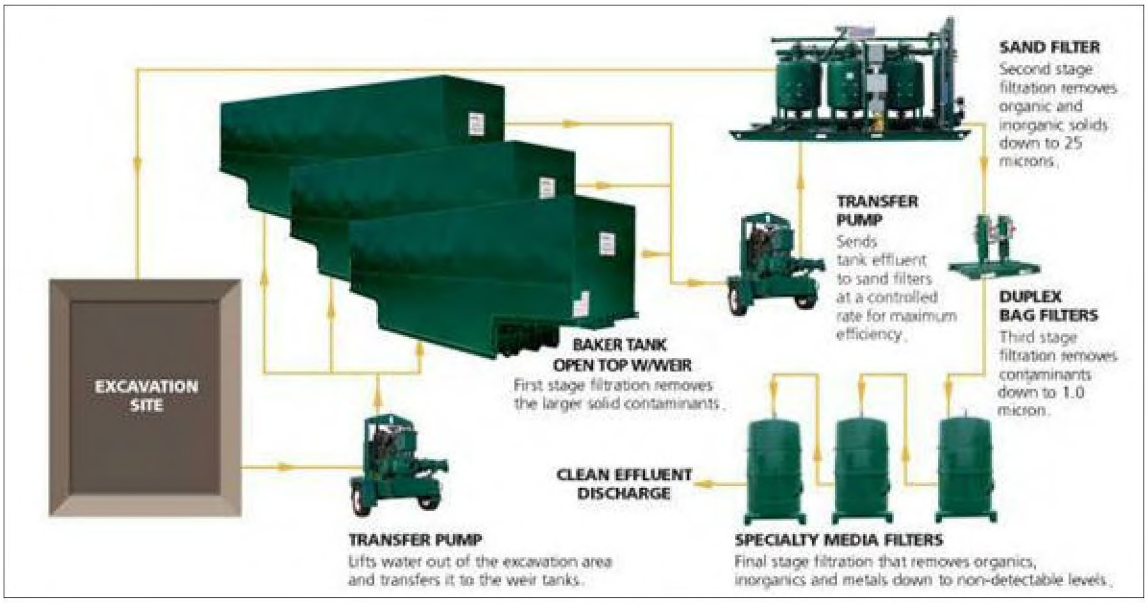


Figure 4-3. Example of Baker Tanks

- The soil profile and selected soil and rock properties are baselined and characterized in the GBR. The City had made a decision to retain risk through the GBR. Considering the relatively wide spacing of geotechnical investigations completed for the GBR and the known variability of subsurface conditions along the guideway alignment, claims for differing site conditions (i.e., variation from baselines in the GBR) will likely occur. The most likely claim probably would be for less competent (than baseline) subsurface conditions that necessitate additional depths of either drilled shafts, including required casing, or increased diameters of drilled shafts. The specification requires permanent casing in areas where soils are soft and underconsolidated, which is defined as shear strength of less than 600 pounds per square foot. Soil ”softness” would principally affect shaft and casing length, but shaft diameter could be affected as well. Depths of shafts may increase from those portrayed in the baseline because the baselines provide broad characterizations but design is based on individual foundation locations. Shaft diameters, however, are predicated on lateral demands that are not as sensitive to variations in shear strength for lateral load support calculations unless a major change is encountered. Since steel casing is identified as a long lead item, a conscious effort was made not to under predict the amount needed. This was reflected in the conservatively setting the Ra baseline, which per contract requires steel casing. Approximately 24 drilled shafts with an average diameter of 7 feet may be exposed to greater depths in soft soils, resulting in a cost of between $3,000 and $5,000 per foot. However, based on information provided in Kiewit’s bid documents, it is unlikely that final design shafts would be shorter than proposed in the contractor’s estimate and assumed in the bid proposal. For reference, the soil profile west of Kunia Road is relatively uniform and can be generalized as competent ground that has relatively little likelihood of significant variations from baselined shear strength, although stratigraphy could vary. Conversely, the subsurface conditions east of Kunia Road become highly variable and have greater risk of differing from baselined conditions.

- Average shaft lengths could be up to 5 feet longer as a plausible worst-case from the bid basis average of approximately 70 feet. (Note: the indicated design shaft depths range from less than 40 feet in the western portion to almost 160 feet for the portion east of Kunia Road.)
- The occurrences of boulders in shaft excavations, which could affect construction production rates, are baselined and the baseline value is judged to be conservative. Boulders are not expected to be hard. An increase in boulders as a percentage of total excavated shaft volume is considered possible, but the risk is considered low.
- The degree of cohesionless materials that may be encountered was baselined as a percentage of total footage. The City is exposed to longer shafts as a result of an increase in percentage of cohesionless materials, but actual impacts would be small considering the difference in shear strength for cohesive and cohesionless materials.
- There is considered to be a 20 to 50 percent chance that longer steel shaft casings would be required through the limited areas of baselined soft soils. Where such an increase in length may be required, the increased length would be limited to no more than an average of 5 feet .
- There is a low likelihood of significant changes in total amount of reinforcement to either drilled shafts or columns. Additional depth of shafts would result in additional reinforcement requirements, however.
- There is a considerable cost in the contract as a whole for the steel in permanent shaft casings and shaft and column reinforcement cages. The special contract provisions retain the risk of price fluctuations greater than 10 percent in the cost of steel. Given the uncertainly in the economy, steel spikes considerably above 10 percent cannot be ruled out. Steel casings would be a long lead item from both a manufacturing and transportation standpoint (transportation to Honolulu is governed by reserving space on barges). Exposure to a cost increase in temporary reusable steel shaft casings is the contractor's responsibility and not a foreseeable risk to the City.
- Street access, control of highway traffic, and available work area were assumed to be adequately portrayed in the contract documents and validated and accepted by Kiewit through its bid. Additional shaft lengths, additional (utility) dewatering requirements, and other identified risk events could not be visualized as significantly or adversely impacting known construction limitations and working methods. Schedule elongation is possible, however, and the City would be exposed to associated costs, such as extended general conditions and head office costs, as well as the direct costs identified.
- The contract requires a sharing of cost savings (e.g., a credit for subsurface conditions being better than that baselined in the GBR). However, the

baselines in the GBR are not conservative (relatively speaking above-average values), which is consistent with the strategy to retain more of the risk and obtain lower, more consistent bids through less extreme guesswork on the part of bidders for those more unlikely risk events.

- Specifically West O'ahu east toward Kunia and Fort Weaver Roads (Section B, Stations 392 through 565) were characterized as one uniform, cohesive, and very stiff (competent) stratum with dry conditions. The small risk of perched water and associated inflow were not baselined. Kiewit's bid-basis shafts through this area range from 40 to 50 feet deep. However, in the initial 400 to 500 feet (impacting perhaps three to four shafts), Kiewit's detailed geotechnical investigations encountered coralline deposits. Coralline deposits, although not defined in the geologic profile, were baselined in the GBR to be present in 10 percent of the shaft locations. Regardless of the baselined percentage of coralline detritus, this occurrence may precipitate a claim or claims from the contractor for possible over-pour (loss of concrete through coral fissures) and overbreak, as well as possible additional time required to construct the shafts.
- Specifically Farrington Highway east of Kunia Road (Waipahu Section C), all shafts are expected to be drilled in wet conditions. The GBR establishes the baseline for groundwater levels and little variation is expected. As such, the associated risk is considered negligible. Kiewit's approach to construction for shafts where water will be encountered is to use casing (e.g., a combination of both temporary and, where required, permanent casing.)
- Progressing east along Farrington Highway from Station 635 through Station 680, the GBR notes high groundwater levels with underlying very poor ground under the fill. Made-up fill is present from between 5 and 20 feet below the ground. The soft ground below the made fill is required by the contract to employ permanent casing, so any risk associated with excavation instability in these poor soils is addressed.
- Similarly, relocation of utilities between Stations 635 and 680 may be more exposed to water-related settlement problems and the need for trench support or more elaborate dewatering methods (e.g., jet grouting /vacuum well points, or other excavation stabilization methods). This could result in claims for additional costs since no baselines were provided for civil improvements. Support of existing old utilities that may be affected by dewatering operations could also require jet grouting to reduce settlement risk along with emergency repairs, the cost of which would most likely fall to the Project.
- The baseline conditions include shallow groundwater and elevated (above existing ground surface) artesian conditions in this Section; however, historical artesian levels have generally been dropping and are not expected to rise so significantly that substantial extra aboveground casing would be required over the current baselined conditions. Casings extending up to 25 feet above the ground surface cannot be completely ruled out, however, if

rainfall and local conditions change significantly over the next two to five years. This Section has approximately 45 drilled shafts that could be affected by higher-than-anticipated water levels.

MSF—Under Contract to Kiewit through a Design/Build Contract

- The assumption is that the Navy has cleared, understood to be through pumping, all diesel leakage from previous vandalism and historical use of the site as a drum filling station for Navy ships and submarines. The likelihood that some contamination still remains in site soils is believed to be low (both in terms of occurrence and concentrations) and per State regulations, would not prevent the soil being reused onsite as fill. Once the site is leveled through cut-and-fill operations, any contaminated soil could be capped to prevent any future threat to human health. If any additional remediation is required due to levels of contaminant exceeding acceptable levels, then the City would claim such costs back from the Navy which has certified the site as "clean."
- The City's investigations show soft soils, which might require soil stabilization or other remediation efforts for the MSF's development at the south end of the site at the base of a moderately gentle slope where a drainage pond is planned. Although these weak and compressible ground conditions do not pose any significant risk to planned pond construction, the soft ground may require mitigation since a relatively high, retained slope will extend above it. Mitigation measures could include pre-loading of soils, wick drains, stone columns, or jet grouting, as well as a combination of these methods, to strengthen the soil. Some allowance for additional costs would be prudent. It should be noted that no baselines were provided for this design/build contract.

Kamehameha Guideway Section D—Under Review by City as Design/Build Contract

- The top of rock is shallower through this section than in the WOFH (Sections B and C).
- As with the WOFH Contract, coralline—although not evidenced in the City's geotechnical investigations—is baselined as a nominal percentage of total shaft location.
- Casings lengths, because of the general variability observed, could increase by $500,000 to $1 million over that currently estimated based on a 10 percent increase in length to that provided for estimating purposes (based on 59 casings). However, there is believed to be little risk of increasing the number of shafts requiring permanent casings—the depth of the casing was seen as the factor that could vary most.
- There were estimated to be 171drilled shafts in this section, including foundations for split bypass track guideway in this section. The GBR baselined conditions show that drilled shaft construction through the entire

contract alignment should be considered as wet. Similar to the WOFH Contract, permanent casing is required where soft soils are penetrated; temporary casing may be required if the water/slurry mix is insufficient to maintain excavation stability, but this risk is considered to be small.

- Drilled shafts average 75 feet deep and are typically 8 feet in diameter. Estimated shaft completion depths range from as little as 40 feet to almost 130 feet; almost 75 percent are 8-feet diameter with the balance being 5-feet diameter (10 percent for balanced cantilevers) and 15 percent as either 9-feet or 10-feet diameter monoshafts.
- Drilling fluid management is undetermined at this time but would generally be subject to the same requirements described for the WOFH Contract. Relative to the slurry management plant (Figure 4-3), it is assumed that slurry plant moves would be minimized. Hose runs of up to 750 feet would be reasonable, and one plant setup could be sited to serve 5 shafts on either side of the plant before a move would be required. The contractor’s site set up would most likely be for 11 shafts to be covered by one slurry/water plant set up (skid). There probably would be two skids and overlap of shaft excavation with concreting. Significantly deeper shafts may require an increased number of water treatment skids to maintain overall progress.
- Boulders are baselined as a percentage of total shaft excavation depths, so there exists some risk, similar to the WOFH Contract, of encountering more boulders than baselined.
- Ground conditions are typically not consistent, and wide variations, as evidenced in the GBR plan and profiles, should be expected.

Airport Guideway Section J—Under Design by City as Traditional Design/Bid/Build Contract

- Of the 272 drilled shafts planned, the estimated completion depths range from just more than 20 feet to 250 feet with an average drilled shaft depth of about 85 feet. Drilled shaft sizes vary from 5 feet diameter (multiple shafts at balanced cantilever foundations) up to 10 feet diameter in deep soft ground areas, such as through the Ke‘ehi interchange area. Almost 70 percent are estimated to be 7 to 8 feet in diameter and approximately 5 percent would be 5-feet diameter multi-shafts. The remaining 25 percent would be 9-feet diameter shafts, and less than a dozen are estimated to be 10-feet in diameter. The 9- and 10-feet diameter shafts are required in soft ground areas and are typically cased.
- Per the Design Criteria, permanent casing is required for the two design/build contracts where drilled shafts penetrate soft ground. This amounts to about 25 percent of the drilled shaft footage.
- Along Nimitz Highway the alignment has been shifted northward and no boreholes have been drilled in this location. However, they will be drilled for the Final Design before the contract is put out to bid.

- Work in the Airport Section was bounded by Navy properties, and work areas are very restrictive. Means and methods, heights of cranes and the like are also constrained by Federal Aviation Administration requirements.
- Ground characterization can be summarized as follows:
  - There is no artesian water pressure present in this Section.
  - Most of the planned drilled shafts will be drilled under wet conditions given that groundwater is typically within 20 feet of the ground surface.
  - Subsurface conditions are highly variable and include varying mixes of competent and soft alluvium, coral deposits, and basalt bedrock.
  - Two very deep soft ground areas exist (Hālawa Stream and the Ke‘ehi interchange/Middle Street Transit Center Station area).
  - Coralline of variable thickness is present at the eastern end of the alignment. The extent of any notable coral extends approximately from the Airport Station where the alignment turns to parallel Nimitz Highway, eastward to the Middle Street Transit Center Station area (the Moanalua and Kalihi Streams area). The Airport is built on coral. As is local practice, shafts would be designed without construction casing (e.g., no permanent casing would be used where foundations penetrate coral/coralline detritus) and assume a representative over pour, which local experience shows to be significantly higher than for shafts constructed in areas without coralline deposits. It is assumed permanent casings would not be used since, even considering a worst-case over pour, they would not be cost-effective given the cost of the casing and the resulting additional depths of the drilled shafts that would be necessary to compensate for loss of frictional support.
- Two very deep soft ground areas exist (Hālawa Stream and Ke‘ehi interchange/Middle Street Transit Center Station area). Based on available information, the drilled shaft foundations through the Hālawa Stream area (approximately a dozen and a half piers) will be up to 250 feet deep. Similarly, the nearly dozen and a half shafts at the eastern end of the Section (through the Moanalua Stream/Ke‘ehi Interchange area) will be up to 235 feet deep. Although a lot of information exists in the Hālawa Stream area to support the preliminary geotechnical designs, it was also noted that a recent bridge project (the adjacent Pearl Harbor-Arizona Bridge) had drilled shaft foundations that only extended down 130 feet, which is considerably less than the 250 feet noted above. No such anomalous information is noted for the soft ground foundations design through the Ke‘ehi interchange area. Furthermore, these two soft ground crossing shafts will need to be permanently cased down to about 130 feet on. Through the Hālawa Stream area there are an estimated 19 piers located in soft ground with drilled shaft depth taken as 250 feet and permanent casing to 118 feet. Casing depth would likely vary from between 80 and 125 feet deep. Through the Moanalua Stream/Ke‘ehi interchange, it has been estimated that there are 20 shafts in soft ground

averaging 230 feet in completion depth. Permanent casing for the soft grounds being penetrated are estimated as 150 feet in length.

- Foundation completion depths, casing lengths, and casing required as estimated for the soft ground area are not likely to increase during Final Design for the reasons discussed above.
- The balance of about 190 guideway pier foundation locations will be drilled in relatively less risky ground conditions at depths of between 25 and 100 feet. Boreholes have been drilled at 25 percent of the locations (approximately one for every five piers). Shafts will be constructed under wet conditions.

City Center Sections E and G—Under Design by City as Traditional Design/Bid/Build Contract

- Less than a dozen geotechnical investigations have been completed for preliminary designs and estimates for this Section. In part this is due to the significant number of previously completed investigations for earlier project studies conducted in the 1990s. However, most historical information is for parallel, but nearby, alignment studies.
- Although subsurface conditions across the Section are variable, geology is similar to the Airport Section and the rate of subsurface change observed is much more gradual, such as where the alignment crosses streams.
- Coralline of variable thickness is present across the City Center alignment. Coralline and coral sand strata thickness vary from only a few feet to over 30 feet Drilled shafts penetrating coral deposits would be designed consistent with local practice, that is not using permanent casing and assuming a representative quantity for over pour.
- Of the approximately 230 drilled shafts planned (180 guideway piers), estimated completion depths range from 35 to almost 260 feet with an average drilled shaft depth of about 80 feet. Drilled shaft sizes vary from 5 feet diameter (multiple shafts at balanced cantilever foundations such as through the Middle Street Transit Center Station area and just east of the Ke‘ehi interchange area) up to 9 feet in diameter in deep soft ground areas. The majority of the drilled shaft foundations are estimated to be 7 or 8 feet in diameter. Approximately 15 percent are estimated to be 5 feet diameter multi-shafts or 9 feet diameter monoshafts. The 9 feet diameter shafts are required in soft ground areas, such as Nu‘uanu and Kapālama Streams, and they are typically assumed to be cased.
- Per the Design Criteria, permanent casing is required for the two design/build contracts where drilled shafts penetrate soft ground. This amounts to about 30 percent of the drilled shaft footage, including soft ground areas.
- Several deep, soft ground areas exist: the Middle Street Transit Center Station/Kalihi Stream area and Kapālama Stream crossing. Based on available information, the approximately two dozen drilled shaft foundations

through these soft ground areas will range between 200 and 260 feet and require permanent casing over half their constructed length.

- Work in the City Center Section will be significantly influenced by limited access, restrictive working hours, and limited lay down space.
- Construction methods will need to be based upon twisting casings into the ground (using oscillator or rotator equipment). Driven casings (and for that matter piling) is not considered practical through this Section because of the close proximity of existing structures.
- All shafts are assumed to be constructed under wet conditions
- The average depth of shafts is 80 feet and the average diameter is 8 feet (at stations, shaft diameters increase to typically 9 feet in diameter). No large drilled shafts of this size have been constructed in Hawai‘i, much less in the City Center.
- Productivity is likely to be significantly below what could be expected in other Sections.

SCC 50—Systems and SCC 70—Vehicles

- The final fare collection system has been determined. There is a risk of additional costs due to any increase in the number of fare collection machines.
- The specification and scope of an emergency power system have been clarified in the BAFO issued to the Core Systems bidders and may result in cost increases over that currently estimated.
- Vehicle numbers aligned to RTD journey times will be clarified in responses to the Core Systems BAFO and may result in additional costs or show savings from those currently included in the estimate.
- There is a risk that the current design of the guideway’s central walkway, may be increased however the workshop noted any increase would most likely be offset by the change to a plinthless track base.
- The workshop was told that the City is seeking vehicles based on tried and tested technology, and the specification did not envisage or require any innovative untested design solutions. As a result, no risks were envisaged regarding unforeseen technological challenges.
- There are no at-grade crossings and therefore no interfaces with the public that could result to a change from totally driverless automated operations.
- The current vehicle design was said to incorporate electromagnetic shielding of sensitive components.
- Other potential specification enhancements deemed not to be risks included onboard HDTV display screens, which would only be added to vehicles if a sponsor was found to cover their complete cost. A change of specification

from metal to aluminum for train car bodies was not an issue under consideration, and onboard fire suppression had not been discussed and was not under consideration either.

SCC 60—Right-of-Way

- The current main concern for ROW is that without a ROD no formal discussions with property owners can occur. This has resulted in limited information being available regarding the number of tenancies in buildings and a lack of knowledge with respect to relocations.
- The ROW cost estimate was believed conservative and has considered these uncertainties with current appraisal values by incorporating a 40 percent contingency on all properties.
- The ROW estimate currently assumes additional costs for possible condemnation.
- The ROW estimate currently allows for additional costs associated with relocations.
- A few properties have been identified that are believed to have additional risks associated with coordination and relocation.
- A limited number of condemnations were expected, and estimated contingency allowances were believed overly pessimistic.

SCC 80—Professional Services

Schedule

- Multiple areas existed where the FTA process may result in delayed approval to commence Final Design. In addition, considerable uncertainty existed in the ability of the Project to secure a start of main construction ahead of the FFGA and without formal LONPs in place. These and other issues also presented risks to the timely granting of the FFGA and posed a cash flow risk to the Project as a whole.
- Risk of protests existed on the bid and award of any and all contracts, and particularly to Core Systems where protests are common place.
- The commitment by the City to procure the Project in small packages to allow for the greatest possible involvement of local labor has resulted in a large number of contract packages, resulting in multiple interfaces. Site access constraints associated with multiple contracts occurring at the same time and in the same area were possible.
- Interim completion dates required for access from civil contractors by the Core Systems contractor were seen as the greatest risk and most difficult to accommodate in early contracts. The objective is to allow maximum flexibility and continuity of Core Systems installations and testing.

Contracts and Procurement

- The issue of insufficient qualified bidders to provide competitive prices was not considered a major risk. With the multiple contracts envisaged that are specifically designed to provide opportunities for the existing workforce, competitive bids were expected in all areas.
- Geotechnical conditions may vary from the GBR, and the City was not intending to pass all ground risk to the bidders.
- With the continuing delay in the signing of the ROD, the value of delay claims currently included in estimates for the WOFH and MSF Contracts may be exceeded.
- The risk of discovery of hazardous materials has been completely retained by the Project. However all material classified as contaminated could go to a local landfill. Any materials classified as hazardous would have to be taken off island due to strict regulations in connection with protection of the island's water supply and aquifer.
- It has been confirmed that there is no conflict with FTA law (49 USC) between the language used in the Project Labor Agreement and Rapid Transit Stabilization Agreement.
- Going forward, the Project Labor Agreements are now in place for all contracts except for WOFH. However, the only action required is for the WOFH contractor to sign the agreement. The current assumption is that the contractor will do this since it is their best interest and will protect them against strikes.
- Maintenance provisions of Hawai'i Department of Transportation ROW have to be incorporated into the WOFH Contract, and the costs have not yet been agreed upon.
- Bankruptcy by a prime contractor or default by a major supplier was discussed and considered to be a low risk as far as affecting the Project and exposure to the City for additional unrecoverable costs. It was believed back-to-back agreements and performance bond agreements will safeguard the City from any consequential costs that may arise from defaults.

5 Cost Analysis

5.1 Methodology for Cost Risk Analysis

Two approaches to cost risk analysis have been adopted: the Bottom-Up Monte Carlo Analysis based on the identified risks and estimate uncertainty, and the FTA Top-Down Beta Range Factor Analysis. Both are described in the following sections.

5.1.1 Bottom-Up Monte Carlo Analysis

A cost risk analysis has been developed independently in MS Excel using the simulation Monte Carlo software "@Risk" distributed by Palisade Corporation. The cost risk model applies estimating uncertainty around the main estimate sections and, in addition, has probabilistic discrete risks identified under each SCC category as identified in the risk register.

The likely outcomes of the combined risk events identified in the risk register were determined by probability simulation with "@Risk" software using Monte Carlo simulation methods. The Latin Hypercube method of sampling has been adopted.

The software is set to run a number of iterations, each representing a single execution of the entire project. For each of the iterations considered in the simulation, the potential risk events are combined randomly and considered to occur (or conversely not occur) in proportion to their estimated probability of occurrence. For example, the impacts of an event that has a 10 percent probability of occurrence will be triggered 1,000 times in 10,000 iterations or project executions. The model has been run through 10,000 iterations to provide representative results and the P10, P50, P80, and P90 figures extracted for reporting purposes (where P = Probability of occurrence or confidence level). Various reports are produced from the analysis software and are contained in the Executive Summary and within this section of the report.

The analysis generally adopts a seven-point cumulative distribution. The use of this distribution as opposed to a triangular, betapert, or trigen distribution is based on the following advantages:

- Removes optimism bias
- Forces ranges to sensible extremes
- Encourages out-of-the-box thinking

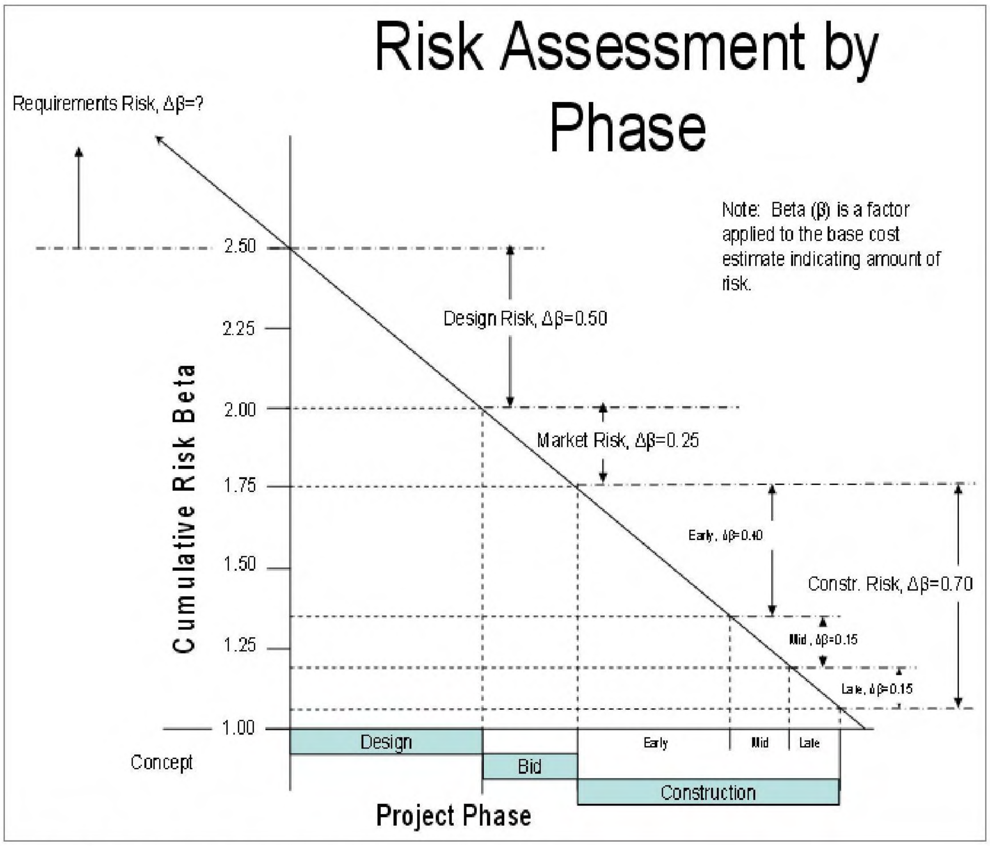
The seven-point distribution analysis incorporates costs provided at the 0, 10, 25, 50, 75, 90, and 100 percentiles. A cumulative distribution has been applied to the entire range to provide what is viewed as a more accurate set of input data points to better reflect the expert opinions provided.

5.1.2 Top-Down Parametric Beta Range Factor Analysis

Based upon the historical information, FTA has developed a model that takes the most optimistic cost estimate (free of contingency with a 10 percent likelihood of success) and the most pessimistic estimate (termed the 90th percentile) to which a LogNormal distribution curve is applied. This results in a cumulative density function (or “S” curve) of likely project cost ranges versus probability. The intention is to produce a more accurate and realistic true-end cost forecast based on past trends. The multiplication factors between the 10th percentile and the 90th percentile are known as the “Beta factors,” now renamed in FTA’s latest Oversight Procedure (OP40) as the Beta Risk Factor or “BRF.” The modeling process has been called a “top-down” analysis in contrast with the traditional risk register-based Monte Carlo analysis that is referred to as the “bottom-up” approach.

The Top-Down Beta Range Factor Analysis is based on OP40 and applies BRFs to a “stripped cost estimate.” The BCE has been stripped of allocated and unallocated contingency. No further reduction for embedded, latent, or patent buried contingency was made. BRFs were applied to the stripped cost estimate in accordance with FTA guidance. FTA developed a profile representing progressive risk reduction across the delivery cycle based loosely around historic trends and adjusted for real-life experiences. Figure 5-1 shows the FTA’s beta reduction triangle.

The correct application of the BRF is dependent upon an adjusted optimistic estimate, from which all contingencies have been removed, including embedded or hidden contingencies in allowances, etc.



Source: FTA Oversight Procedure 40—Risk and Contingency Review

Figure 5-1. Beta Range Factor Allocation Diagram

5.2 Stripped Adjusted Cost Estimate

5.2.1 Introduction

Both the bottom-up and top-down risk analysis models are based upon a stripped cost estimate as a starting point for evaluation of risk.

As part of this risk assessment, a stripped cost estimate was developed. The stripped cost estimate has been arrived at through a detailed review of the cost estimate to remove all embedded contingency funds. Such contingency funds identified to be removed have included both unallocated contingency funds and allocated contingency funds. Both patent (or exposed) contingency funds and latent (or hidden) contingency funds have also been identified. Further contingent funds that are believed to be embedded within estimates for inflation or escalation risk have also been reflected in the analysis and computation of the stripped cost estimate.

Having removed all contingency, the project scope was validated by reviewing the information derived through the risk assessment process in the discussions and analysis of the following:

- Current assumptions around rail capacity/operating plan
- Agency's technical capacity given the planned program of projects over the next 10 years
- The identified environmental constraints and NFPA 130 issues
- The currently proposed contracting plan, associated schedule, and cash flow
- Rates, quantities, and allowances derived from historical costs

Adjustments were then made to the stripped cost estimate to reflect the review of the Project as outlined above, and the stripped cost estimate was further revised, increasing or decreasing the various estimate line items to produce an Adjusted Cost Estimate. The following sections detail the adjustments made to each contract package.

5.2.2 Removal of Allocated Contingency

The first step in producing the stripped cost estimate was to use the base year estimate and remove all identified allocated contingency. Table 5-1 shows the allocated contingency that was removed from each contract package.

Table 5-1. Removal of Allocated Contingency

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5.2.3 Removal of Latent Contingency

To further strip the estimate of all contingency, any hidden or latent contingency in the estimate was identified. This section explains the reasoning behind the removal of $199 million latent contingency for all contracts. Table 5-2 summarizes the base cost estimate in 2010 dollars for each contract package and also the amount of latent contingency removed and the resulting stripped estimate.

Table 5-2. Removal of Latent Contingency

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Contracts with No Latent Contingency Removed

The following contracts were believed to not have any hidden contingency given that bids have been submitted and some have been awarded:

- WOFH
- MSF
- Kamehameha

Guideway Contracts

The two guideway contracts listed below had the same amount of latent contingency identified and removed:

- Airport Section
- City Center Section

Based on discussions with the estimating team, it was believed that 3 percent could be removed to account for conservative rates used in the original estimate.

Earlier discussions with the geotechnical team determined that the geotechnical design for both the Airport and City Center Sections were conservative. Based on this information, a 10 percent reduction of the total cost of piles was taken.

Station Contracts

All station contracts, listed below, had a total of 5 percent latent contingency identified and removed:

- WOFH Stations
- Kamehameha Stations
- Airport Stations
- City Center Stations

To identify the amount of latent contingency, the estimating team reviewed the original estimate produced and found conservative rates were applied to the various estimate components. When more optimistic rates were applied, the total cost for stations was reduced by about 5 percent. See Appendix D for an example of the process used to identify the latent contingency.

Systems Contract

With two bidders currently in the process of determining BAFO, it was believed that a 10 percent savings could be achieved. Minimal information is currently available due to the level of confidentiality required.

A $10.5 million reduction in SCC 80.08—Start-Up was also taken due to the change of six startups to three, which has not been reflected in the estimate. To arrive at that amount, it was assumed that 40 percent of the $52.7 million cost was related to startup, which is $21 million. The $21 million was then decreased by 50 percent since there was a 50 percent reduction in the number of startups.

Right-of-Way

To determine additional contingency embedded in the ROW estimate, the ROW team produced a most optimistic cost estimate, which is shown in **Table 5-3**. $49.5 million in allocated contingency was removed, along with an additional $41 million in latent contingency, for a total of $90.5 million. The optimistic cost estimate assumed the following:

- Adjustment to acquisition costs of properties deemed to not be required – from the Final Environmental Impact Statement and optimistic design.
- Reduction of acquisition allowance for settlements
- Removal of additional contingency

Description	BCE Totals	Optimistic Total
SCC 60.01	**$153,685,152**	
Acquisition Costs	$128,039,049	$106,190,869
Condemnation Costs	$20,220,000	$1,200,000
Closing Costs (.5% of Acq. Costs)	$640,195	$530,954
Administrative City Costs	$4,785,908	$4,785,908
SCC 60.02	**$14,482,506**	
Relocation Costs	$14,482,506	$14,482,506
Allocated Contingency	**$67,267,064**	
Acq. Allowance (For Settlements)	$49,454,781	$17,812,283
Additional Contingency	$17,812,283	
Total	**$235,434,722**	**$145,002,520**

Elevators and Escalators

Latent contingency identified for the elevators and escalators contract produced a 10 percent reduction. Discussions with the estimating team verified that rates used were fairly conservative and additional savings could be obtained given that the contract also includes maintenance for at least five years.

Utilities by Utility Companies (Electric and Telecomm)

Based on conservative rates used by the estimating team, 3 percent of latent contingency was identified and removed.

Owner Furnished Plants and Shrubs

Based on conservative rates used by the estimating team, 3 percent of latent contingency was identified and removed.

City and County of Honolulu

To produce a more optimistic cost estimate, it was assumed that if the total time of the Project was reduced by six months, a cost savings of 5 percent would be achieved for the following professional services:

- SCC 80.03
- SCC 80.06

SCC 80.05 was also reduced by $10 million for potential savings by going to an OCIP.

A $3.8 million reduction in SCC 80.08—Start-Up was also taken due to the change from six startups to three, which has not been reflected in the estimate. To arrive at that amount, it was assumed that 40 percent of the $19.4 million cost was related to startup, which is $7.7 million. The $7.7 million was then decreased by 50 percent since there was a 50 percent reduction in the number of startups.

CE&I

To produce a most optimistic cost estimate, an assumption was made that if the total time of the project was reduced by six months, a cost savings of 5 percent would be achieved for the following professional services:

- SCC 80.04

Program Management and Construction Management

To produce a most optimistic cost estimate, an assumption was made that if the total time of the project was reduced by six months, a cost savings of 5 percent would be achieved for the following professional services:

- SCC 80.03
- SCC 80.04
- SCC 80.06
- SCC 80.07

5.2.4 Adjustments

The final stripped estimate resulted in a total cost of $3,367 million, a reduction of $814.2 million in both allocated and latent contingency. Table 5-4 shows the adjustments made to the stripped estimate to arrive at an adjusted stripped cost estimate.

Table 5-4. Adjustments to Arrive at Adjusted Stripped Estimate

Information in this table is commercially sensitive and has been excluded from this report. Following adjustments for favorable market conditions and scope, the stripped estimate has increased from $3,367 million to $3,420 million.

Favorable Market Conditions Adjustment

The station contracts and the elevators and escalators contract had a 5 percent reduction applied to account for the likelihood of favorable local markets, with more than three bidders for each contract. The base estimate was produced on the assumption that there would be three bidders. A competitive market means that additional savings can be assumed.

Added Scope Adjustment

WOFH

An amount was added to cover negotiation and settlement of claims associated with delays to NTP's together with insurance coverage required until the OCIP is in place.

MSF

An amount was added to cover the additional costs that will be incurred by the contractor for providing additional insurance coverage until the OCIP is in place.

Kamehameha

An amount was added to cover the potential of additional costs associated with either a new or expanded casting yard and additional costs that will be incurred by the contractor for providing insurance coverage until the OCIP is in place. Both items were not included in the original estimate, and given that the Kamehameha and WOFH Sections will be constructed in parallel, additional casting yard capacity may be required depending on the contractor selected.

Systems

An amount was added to cover the additional costs that will be incurred by the contractor for providing additional insurance coverage until the OCIP is in place.

5.2.5 Adjustment for Inflation to Year of Expenditure

The final step in producing the stripped adjusted cost estimate is to inflate to the YOE. The total cost arrived at for the adjusted stripped cost estimate at YOE is $3.915 billion (Table 5-5).

Table 5-5. Adjusted Stripped Cost Estimate at YOE

Information in this table is commercially sensitive and has been excluded from this report. Following adjustments for inflation, the adjusted stripped estimate has increased from $3,420 million to $3,916 million.

Table 5-6 provides the inflation rate used for developing the adjusted cost estimate and is a rate that is stripped of contingency in a manner similar to other estimate line items. The rates are based on the *Cost Escalation Forecast Report* dated June 2010. The estimate has been inflated to the YOE adopting the most optimistic assumptions with respect to inflation, which forms the basis for the input to the ensuing risk assessment.

Table 5-6. Most Optimistic Inflation by Commodity

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To produce the actual escalation rate to use for each contract package, a cash flow analysis was provided using the most likely escalation and the optimistic escalation. Shown in Table 5-7 is the average escalation, both most likely and optimistic, incurred by each contract package over the life of the Project. The optimistic inflation calculation equates to an approximate 3 percent annual inflation rate.

Table 5-7. Most Likely and Optimistic Escalation for Each Contract

Contract Packages	Most Likely Escalation	Optimistic Escalation
West O'ahu/Farrington Highway Guideway	6%	6%
Maintenance and Storage Facility	11%	11%
Kamehameha Guideway	15%	12%
West O'ahu/Farrington Highway Stations	30%	23%
Kamehameha Highway Stations	22%	16%
Airport Guideway	25%	18%
Airport Stations	32%	23%
City Center Guideway	31%	24%
City Center Stations	36%	25%
Systems	20%	17%
Elevators and Escalators	25%	19%
Utilities by Utility Companies	11%	10%
Right of Way	3%	0%
Owner Furnished Plants and Shrubs	24%	18%
Final Design	11%	8%
City and County of Honolulu	21%	14%
CE&I	22%	17%
PM	16%	13%
Total	**18.8%**	**14.7%**

5.3 Cost Risk Analysis Results

5.3.1 Summary Results

The bottom up cost risk analysis provides a 70 percent confidence in completing the Project at or below the current BCE YOE of $5.167 billion. To reach the recommended 80 percent confidence level, an additional $136 million in contingency is required.

The top-down cost risk analysis indicates the Project's current BCE YOE is below the calculated 30th percentile of $5.177 billion and requires an additional $145 million in contingency. Full analysis results are provided in Table 5-8.

Table 5-8. Summary Cost Risk Analysis Results

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5.3.2 Top Down Cost Analysis

Results

FTA's OP40 stipulates a budget equivalent to a 30th percentile confidence point on the top-down model "S" curve for entry into Final Design. In addition, OP40 stipulates a required contingency of 20 percent of the stripped cost estimate for entry into Final Design. The risk analysis proposes this target confidence of 30 percent normally associated with entry into Final Design be adopted at the current milestone of 40 percent bid (refer to Section 7.2) since entry into Final Design has yet to be approved and the Project is awaiting a ROD. Figure 5-2 illustrates the cumulative density function of the top down cost risk analysis.

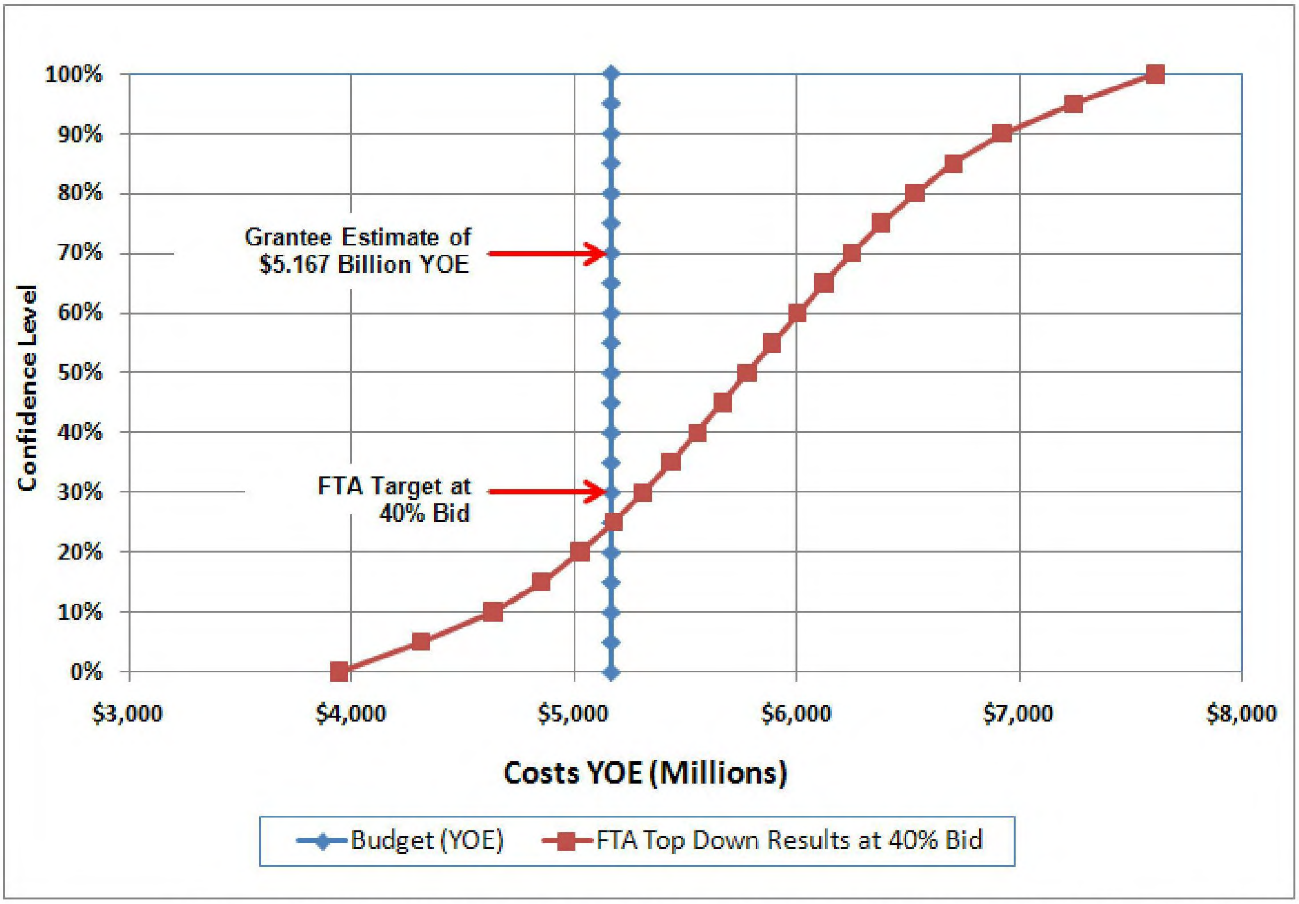

Figure 5-2. Cumulative Density Function of Top-Down Cost Risk Analysis

Approach

See Section 5.1.2 for the methodology used in producing the top-down model.

Table 5-9 shows the BRFs assigned to the 10th percentile (stripped and adjusted base cost estimate) at each SCC as input to the top-down beta model at the current phase milestone of 40 percent bid (prior to entry into Final Design).

The BRFs represent all risk exposure on a project and are applied to each aspect of the work. Appendix E provides the BRFs assigned to all FTA milestones along with notes as to the reasoning for each BRF.

Table 5-9. Beta Range Factors Assigned at Current Milestone 40 Percent Bid (prior to Entry into Final Design)

SCC	Category	Total P10	Total Beta
SCC 10	**Guideway and Track Elements**		
10.01	Guideway: At-grade exclusive right-of-way	0	1.00
10.02	Guideway: At-grade semi-exclusive (allows cross-traffic)	0	1.00
10.03	Guideway: At-grade in mixed traffic	0	1.00
10.04	Guideway: Aerial structure	1,043,263,009	1.94
10.05	Guideway: Built-up fill	0	1.00
10.06	Guideway: Underground cut & cover	0	1.00
10.07	Guideway: Underground tunnel	0	1.00
10.08	Guideway: Retained cut or fill	7,635,624	1.50
10.09	Track: Direct fixation	43,150,029	1.64
10.10	Track: Embedded	0	1.00
10.11	Track: Ballasted	3,563,164	1.50
10.12	Track: Special (switches, turnouts)	7,195,378	1.68
10.13	Track: Vibration and noise dampening	0	1.00
SCC 20	**Stations, Stops, Terminals, Intermodal**		
20.01	At-grade station, stop, shelter, mall, terminal, platform	6,528,126	2.30
20.02	Aerial station, stop, shelter, mall, terminal, platform	321,997,057	2.35
20.03	Underground station, stop, shelter, mall, terminal, platform	0	1.00
20.04	Other stations, landings, terminals: Intermodal, ferry, trolley, etc.	0	1.00
20.05	Joint development	0	1.00
20.06	Automobile parking multi-story structure	52,741,949	2.30
20.07	Elevators and escalators	52,455,653	2.70
SCC 30	**Support Facilities: Yard, Shops, Administration Buildings**		
30.01	Administration Building: Office, sales, storage, revenue counting	0	1.00
30.02	Light maintenance facility	10,093,505	1.50
30.03	Heavy maintenance facility	40,255,809	1.50
30.04	Storage or maintenance of way building	8,039,286	1.50
30.05	Yard and yard track	77,763,838	1.50
SCC 40	**Sitework and Special Conditions**		
40.01	Demolition, clearing, earthwork	11,606,852	1.99
40.02	Wet utility relocation	89,262,604	3.50
40.02ET	Electrical and telecom utility relocation	181,051,004	3.13
40.03	Hazmat, contaminated soil removal/mitigation, ground water treatments	1,587,610	2.09
40.04	Environmental mitigation, e.g., wetlands, historic/archeologic, parks	18,016,782	2.14
40.05	Site structures including retaining walls, sound walls	17,515,953	1.97
40.06	Pedestrian / bike access and accommodation, landscaping	45,394,683	2.20
40.07	Automobile, bus, van accessways including roads, parking lots	131,187,141	2.19
40.08	Temporary facilities and other indirect costs during construction	203,588,807	1.50
SCC 50	**Systems**		
50.01	Train control and signals	66,644,832	1.80
50.02	Traffic signals and crossing protection	15,019,693	2.10
50.03	Traction power supply: Substations	31,400,650	1.80
50.04	Traction power distribution: Catenary	39,129,891	1.68
50.05	Communications	48,378,466	1.80
50.06	Fare collection system and equipment	10,229,996	1.80
50.07	Central control	14,311,620	1.80
Construction Subtotal (10 - 50)		2,599,009,010	

SCC	Category	Total P10	Total Beta
SCC 60	**ROW, Land, Existing Improvements**		
60.01	Purchase or lease of real estate	130,520,014	2.00
60.02	Relocation of existing households and businesses	14,482,506	2.00
SCC 70	**Vevhicles**		
70.01	Light rail	302,479,741	1.80
70.02	Heavy rail	0	1.00
70.03	Commuter rail	0	1.00
70.04	Bus	0	1.00
70.05	Other	0	1.00
70.06	Non-revenue vehicles	12,540,063	1.80
70.07	Spare parts	4,101,263	1.80
SCC 80	**Professional Services (applies to Cats. 10-50)**		
80.01	Preliminary Engineering	56,655,288	1.05
80.02	Final Design	192,298,471	1.80
80.03	Project management for design and construction	288,419,169	1.90
80.04	Construction administration and management	169,986,427	2.08
80.05	Professional liability and other non-construction insurance	36,688,167	2.30
80.06	Legal; permits; review fees by other agencies, cities, etc.	59,857,599	1.92
80.07	Surveys, testing, investigation, inspection	6,457,515	1.75
80.08	Start up	42,162,619	1.95
Subtotal (10 - 80)		3,915,657,854	
SCC 100	**Finance Charges**		
100.01	Finance charges	0	1.00
	TOTAL	3,915,657,854	2.03

5.3.3 Bottom-Up Monte Carlo Analysis

Results

Figure 5-3 shows the "S" curve of the Bottom-Up Monte Carlo Analysis.

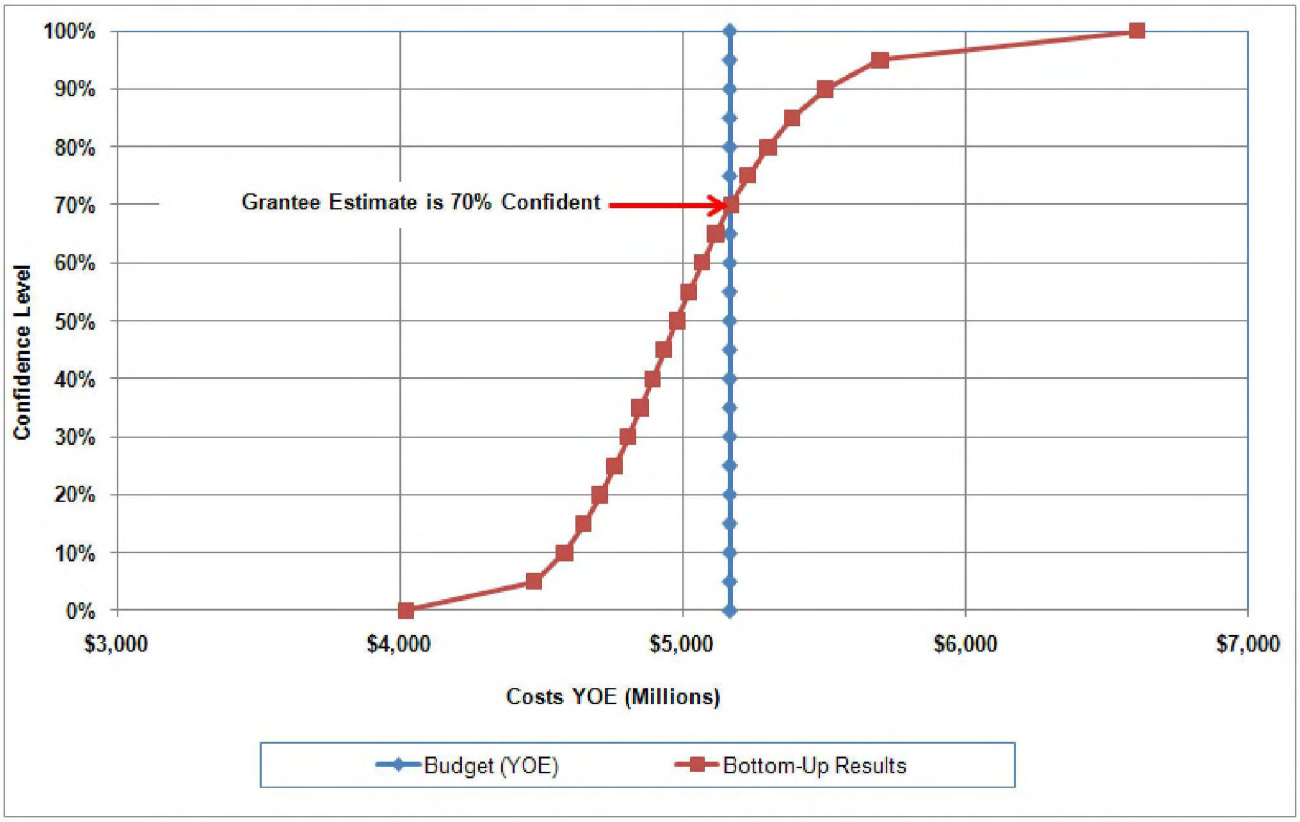

Figure 5-3. Cumulative Density Function of Bottom-Up Monte Carlo Analysis

The Bottom-Up Monte Carlo Analysis produced results for each contract package. Table 5-11 provides a recommendation in changes to the contingency allocated to each contract package and is based on an 80 percentile confidence level.

Table 5-10 shows the range of costs produced by the analysis.

Table 5-11 provides a recommendation in changes to the contingency allocated to each contract package and is based on an 80 percentile confidence level.

Table 5-10. Bottom-Up Model Results for Each Contract Package (YOE)

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Table 5-11. Recommendations to Changes of Contingency to Each Contract Package (YOE)

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Approach

Ranges to the Adjusted Stripped Cost Estimate

The input data to the cost risk model are outlined in this section. The starting costs used in the bottom-up cost model were the costs produced from the adjusted stripped cost estimate in 2010 dollars, as described in Section 5.2. To account for uncertainty, the stripped costs were ranged with a seven-point distribution. Table 5-12 provides the ranges used and the reasoning behind the ranges.

Incorporation of Discrete Risks

To further determine the impact of identified risks, discrete risks were also added to the model. Discrete risks are risks that are identified in the risk register and were deemed as outside of the ranges applied to the adjusted stripped estimate. The pricing and probability of the risks reflected the impact scoring shown in the risk register (Appendix B). The probability of the risk occurring and the range of possible costs have been based on a seven-point cumulative distribution.

Schedule Delay

Schedule delay, the possibility of claims for equitable adjustment levied against RTD for unforeseen events and/or adjustments allowed for under the design or construction contracts, has been calculated by taking the results of the schedule risk analysis and integrating it with the results of the cost analysis and applying a cost of schedule delay factor. This factor is calculated based upon the likelihood of when delays are most likely to occur and the work taking place at those times likely to be affected through prolongation, disruption, nonproductive labor, and other possible conditions. Impacts identified against a number of risks contained in the risk register have been grouped under the schedule delay factor as their impact is viewed as partly or wholly associated with schedule delay.

Design Changes

To account for the risk that changes to the design may occur, a percentage increase for each contract package was ranged in the model, as shown in Table 5-13. These percentages allow for risks identified in the risk register not specifically modeled as discrete events, as well as make allowance for unidentified risk events based on historical norms.

Table 5-12. Ranges of Increases Applied to Adjusted Stripped Cost Estimate

SCC Description		Range 0%	10%	25%	50%	75%	90%	100%	Notes
West O'ahu/Farrington Highway Guideway									
10	Guideway and Track Elements	100%	100%	100%	100%	100%	100%	100%	Bids have been received and incorporated in base estimate. Costs will not vary.
40	Sitework & Special Conditions	100%	100%	100%	100%	100%	100%	100%	
80	Professional Services	100%	100%	100%	100%	100%	100%	100%	
Maintenance and Storage Facility									
10	Guideway and Track Elements	100%	100%	100%	100%	100%	100%	100%	Bids have been received and incorporated in base estimate. Costs will not vary.
30	Support Facilities	100%	100%	100%	100%	100%	100%	100%	
40	Sitework & Special Conditions	100%	100%	100%	100%	100%	100%	100%	
50	Systems	100%	100%	100%	100%	100%	100%	100%	
80	Professional Services	100%	100%	100%	100%	100%	100%	100%	
Kamehameha Guideway									
10	Guideway and Track Elements	100%	100%	100%	100%	100%	100%	100%	Bids have been received and incorporated in base estimate. Costs will not vary.
40	Sitework & Special Conditions	100%	100%	100%	100%	100%	100%	100%	
50	Systems	100%	100%	100%	100%	100%	100%	100%	
80	Professional Services	100%	100%	100%	100%	100%	100%	100%	
West O'ahu/Farrington Highway Stations									
20	Stations, Stops, and Terminals	97%	100%	105%	111%	112%	113%	115%	Most likely at 111% accounts for accuracy uncertainty at 5% and an additional 6% for errors and omissions.
40	Sitework & Special Conditions	97%	100%	105%	111%	112%	113%	115%	
Kamehameha Highway Stations									
20	Stations, Stops, and Terminals	97%	100%	105%	111%	112%	113%	115%	Most likely at 111% accounts for accuracy uncertainty at 5% and an additional 6% for errors and omissions.
40	Sitework & Special Conditions	97%	100%	105%	111%	112%	113%	115%	
Airport Guideway									
10	Guideway and Track Elements	97%	100%	105%	111%	112%	113%	115%	Most likely at 111% accounts for accuracy uncertainty at 5% and an additional 6% for errors and omissions.
40	Sitework & Special Conditions	97%	100%	105%	111%	112%	113%	115%	
50	Systems	97%	100%	105%	111%	112%	113%	115%	
Airport Stations									
20	Stations, Stops, and Terminals	97%	100%	105%	111%	112%	113%	115%	Most likely at 111% accounts for accuracy uncertainty at 5% and an additional 6% for errors and omissions.
40	Sitework & Special Conditions	97%	100%	105%	111%	112%	113%	115%	
City Center Guideway									
10	Guideway and Track Elements	97%	100%	105%	111%	112%	113%	115%	Most likely at 111% accounts for accuracy uncertainty at 5% and an additional 6% for errors and omissions.
20	Stations, Stops, and Terminals	97%	100%	105%	111%	112%	113%	115%	
40	Sitework & Special Conditions	97%	100%	105%	111%	112%	113%	115%	
50	Systems	97%	100%	105%	111%	112%	113%	115%	
City Center Stations									
20	Stations, Stops, and Terminals	97%	100%	105%	111%	112%	113%	115%	Most likely at 111% accounts for accuracy uncertainty at 5% and an additional 6% for errors and omissions.
40	Sitework & Special Conditions	97%	100%	105%	111%	112%	113%	115%	
Systems									
40	Systems	100%	100%	100%	100%	100%	100%	100%	Initial bids have been received but have not been incorporated in the base estimate.
50	Systems	100%	100%	100%	100%	100%	100%	100%	
70	Vehicles	100%	100%	100%	100%	100%	100%	100%	
80	Professional Services	100%	100%	100%	100%	100%	100%	100%	
Elevators and Escalators									
20	Stations, Stops, and Terminals	95%	100%	102%	108%	115%	125%	130%	Larger cost range due to the wide range of costs for elevators and escalators by various manufacturers.

Table 5-12. Ranges of Increases Applied to Adjusted Stripped Cost Estimate (continued)

SCC Description		Range							Notes
		0%	10%	25%	50%	75%	90%	100%	
Utilities by Utility Companies									
40	Sitework & Special Conditions	95%	100%	105%	110%	120%	140%	160%	Utilities have been quantified and costed in estimate, however as with most projects, utility costs remain a large uncertainty until bids have been received and even then until the relocations have been completed.
Right of Way									
60	ROW, Land, Existing Improvements	95%	105%	110%	120%	125%	135%	180%	ROW is major area of uncertainty at this time. Contact with property owners has yet to be made to determine assessed property values. Base Cost, excluding contingency is lowest possible value that properties could be obtained. Decrease possible if number of properties are reduced.
Owner Furnished Plants and Shrubs									
40	Sitework & Special Conditions	85%	100%	103%	105%	110%	115%	120%	Owner Furnished Landscaping has been estimated by quantities, however, given the current level of design additional landscaping costs may be seen in the future - larger cost variance has been given.
Final Design									
80	Professional Services	95%	98%	100%	105%	108%	110%	115%	FD Services is more unknown than other Professional Services so a larger cost range increase has been assumed
City and County of Honolulu									
80	Professional Services	98%	103%	105%	108%	110%	112%	115%	Professional Services have less uncertainty from other categories. Major reason for variance would be due to increase in contract cost and/or project schedule, which has mostly been captured in SDF. Slight decrease could occur depending on contract negotiations.
CE&I									
80	Professional Services	95%	98%	100%	103%	105%	108%	110%	Professional Services have less uncertainty from other categories. Major reason for variance would be due to increase in contract cost and/or project schedule, which has mostly been captured in SDF. Slight decrease could occur depending on contract negotiations.
PM									
80	Professional Services	98%	103%	105%	108%	110%	112%	115%	Professional Services have less uncertainty from other categories. Major reason for variance would be due to increase in contract cost and/or project schedule, which has mostly been captured in SDF. Slight decrease could occur depending on contract negotiations.

Table 5-13. Change Orders during Design

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Occurrence of Changes during Construction

To account for the impact of change orders that may occur during construction, a percentage increase for each contract package was ranged in the model, as shown in Table 5-14. These percentages allow for risks identified in the risk register not specifically modeled as discrete events, as well as make allowance for unidentified risk events based on historical norms.

Table 5-14. Change Orders during Construction

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Market Forces

The possibility of a less-than-competitive market was also accounted for. Contracts that were believed to have a chance of receiving less than three bidders were given varying probabilities of occurrence and increases in contract prices, as shown in Table 5-15.

Table 5-15. Market Forces

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Escalation

To produce an average escalation rate incurred by each contract package over the life of the Project, a cash flow analysis was provided using the most likely, optimistic, and pessimistic escalation rates provided in the *Cost Escalation Forecast Report* dated June 2010. Table 5-16, Table 5-17, and Table 5-18 show the annual escalation rates outlined in the report.

Table 5-16. Optimistic Escalation by Commodity

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Table 5-17. Most Likely Escalation by Commodity

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Table 5-18. Pessimistic Escalation by Commodity

The image cannot be displayed. Your computer may not have enough memory to open the image, or the image may have been corrupted. Restart your computer, and then open the file again. If the red x still appears, you may have to delete the image and then insert it again.

The cash flow analysis provided average escalation rates to use for each contract package. To properly model the uncertainty of escalation, a seven-point distribution was used. The most likely rates were used for the 50th percentile; the optimistic rates were used for the 10th percentile; and the pessimistic rates were used for the 90th percentile**.** Table 5-19 shows the escalation that has been applied to the results of the risk analysis.

Table 5-19. Inflation Risk Table

	0%	10%	25%	50%	75%	90%	100%
Contract Package	50% of 10%'ile	Optimistic Inflation Calculated from PB Report	Avg. of 10%'ile and Most Likely	Most Likely Inflation Calculated from PB Report	25% More than Most Likely	Pessimistic Inflation Calculated from PB	Assume 10% Greater than 90%'ile
West O'ahu/Farrington Highway Guideway*	6.23%	6.23%	6.23%	6.23%	6.24%	6.25%	6.26%
Maintenance and Storage Facility**	10.76%	10.76%	10.76%	10.76%	10.77%	10.78%	10.79%
Kamehameha Guideway	5.89%	11.78%	13.59%	15.40%	16.41%	17.43%	19.17%
West O'ahu/Farrington Highway Stations	11.46%	22.91%	26.34%	29.77%	32.38%	35.00%	38.50%
Kamehameha Highway Stations	8.08%	16.16%	19.24%	22.31%	22.89%	23.46%	25.81%
Airport Guideway	8.99%	17.98%	21.52%	25.05%	27.08%	29.12%	32.03%
Airport Stations	11.53%	23.07%	27.52%	31.97%	34.59%	37.21%	40.93%
City Center Guideway	12.08%	24.16%	27.44%	30.72%	32.86%	35.00%	38.50%
City Center Stations	12.40%	24.80%	30.55%	36.30%	39.32%	42.33%	46.57%
Systems	8.75%	17.50%	18.96%	20.43%	26.62%	32.81%	36.09%
Elevators and Escalators	9.45%	18.90%	21.93%	24.96%	26.31%	27.66%	30.43%
Utilities by Utility Companies	4.93%	9.86%	10.62%	11.38%	13.28%	15.17%	16.69%
Right of Way	0.00%	0.00%	1.67%	3.34%	7.57%	11.80%	12.98%
Owner Furnished Plants and Shrubs	8.76%	17.53%	20.99%	24.46%	27.23%	30.00%	33.00%
Final Design	4.19%	8.37%	9.73%	11.09%	12.55%	14.00%	15.40%
City and County of Honolulu	7.23%	14.46%	17.73%	21.01%	22.26%	23.51%	25.86%
CE&I	8.62%	17.24%	19.77%	22.31%	26.90%	31.49%	34.64%
PM	6.33%	12.65%	14.41%	16.18%	17.09%	18.00%	19.80%

*WOFH Guideway escalation is not ranged since it represents the escalation included in awarded bid.
**MSF escalation is not ranged since it represents the escalation included in awarded bid.

To further account for the possibility of inflation spikes in specific materials, an additional risk was added to each contract, as shown in Table 5-20. A 20 percent probability of occurrence was given along with a three-point optimistic, most likely, and pessimistic distribution.

Table 5-20. Inflation Spike Risk Table

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6 Schedule Analysis

6.1 Methodology for Schedule Risk Analysis

The schedule and risk simulation software used for the analysis is Primavera P6 with Primavera Risk Analysis (previously known as Pertmaster Professional + Risk).

Primavera Risk Analysis is a simulation tool that reads the probabilistic data (activity risk ranges, probabilities of risk occurring, correlation and the like) from the Primavera schedule and then runs multiple calculations on the data to calculate float and critical paths given different activity durations (based on the ranges of duration each could take). It summarizes that data in the form of a statistical report and cumulative "S" curve that provides confidence levels in achieving the whole, or any part, of the schedule. The Primavera Risk Analysis tool provides exceptional graphic reporting capabilities using the Primavera-generated data and also produces sensitivity, criticality, and cruciality indexes.

The risk schedule is a critical path network with all activity ends closed, which is essential if a Monte Carlo risk simulation is to be conducted. Large networks are not suitable for schedule risk analysis and are likely to produce incorrect results.

The risk schedule is a simplified critical path network and, while trying to incorporate all sections of the project for completeness, only includes those activities believed to be key and critical to the Project's completion and relevant to the risk assessment.

Many lower-level activities are "rolled up" into more global activities shown to the extent that they are relevant to the risk analysis. Caution should be used when comparing a schedule developed for risk assessment to one specific to a project's planning schedule, as activities may appear shortened in duration or completely removed. Three-point estimates for each activity in the risk schedule model (minimum, most likely, and maximum) have been developed.

Where activities have been determined to have discrete risks beyond those that could be captured in range on the applicable activity, these have been modeled using the "probabilistic branching" function where unusual risk events associated with a given activity are considered through the incorporation of successor activities in the schedule model. A node links the activity under consideration to two or more "branch activities" with durations that reflect various risk events.

Each branch is assigned a probability of occurrence. The finish of each branch is tied to the activity that previously succeeded the schedule activity being modeled (Figure 6-1).

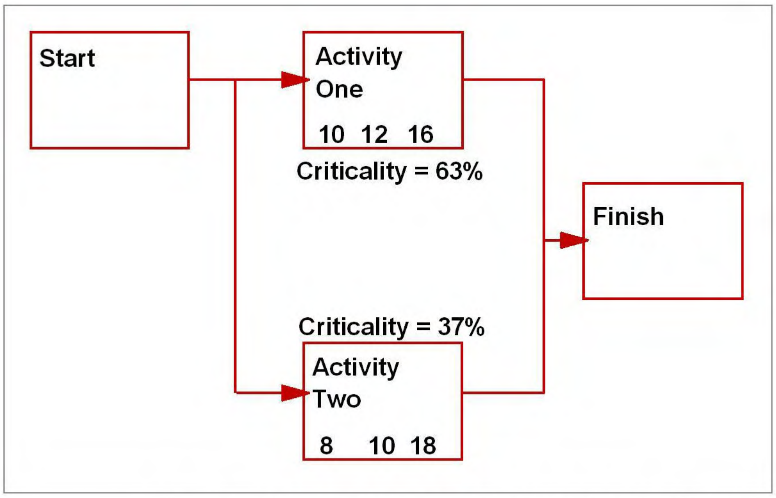

Figure 6-1. Example Probabilistic Branch

Correlation has been applied to the schedule risk model to FTA activities suggesting an accelerated process occurs for entry into Final Design and granting of LONPs, as well as a favorable timescale that progresses to an FFGA. Conversely correlation also models the impact of a protracted process. Logic linkage in this high-level schedule is believed to account sufficiently for correlation.

The schedule risk model was run through 5,000 iterations. Various reports are produced from the analysis and are provided below.

6.2 Schedule Risk Model Development

RTD's current schedule dated December 10, 2010, was used as the basis for the schedule risk model. A summarized schedule was developed and activity durations were adjusted to reflect their most optimistic duration free from any allowances for risk or "latent float." "Latent float" is float that is included in activity durations and is better pulled out and separated as specific float durations termed "buffer" or intermediate float. The expression "buffer" describes float inserted within the critical or near critical path activities to absorb delays within the schedule directly related to perceived risks in those preceding activities. The stripped schedule with buffer float allocation is included as Appendix F.

Buffer float has been allocated to reflect PB's view of the most likely float capacity required to absorb the identified risks. Total float and distribution of buffer float has been assigned to achieve the FTA OG40 schedule float capacity recommendations as follows:

- At the RCD, schedule contingency requirements have been reduced to a minimum requirement or possibly eliminated
- At the point of 100 percent complete with bid or 100 percent subcontracted, the Project should have sufficient schedule contingency available to absorb a schedule delay equivalent to 20 percent of the duration from entry into Final Design through revenue operations.

Table 6-1 shows the calculation of buffer float.

Table 6-1. Calculation of Schedule Buffer Float

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The buffer float shown in Table 6-2 through Table 6-9 has been added to the schedule to absorb the impacts of potential identified risk and to comply with the FTA minimum scope requirements. It is noted where buffer float is on the critical path based solely on achieving the planned 2019 complete opening. Buffer float has also been added on the critical and near critical paths to each Section schedule based on the Section's planned completion in isolation—itself critical but unrelated to the Project's overall completion. The projected completion date if all identified buffer float was used is December 2019.

Table 6-2. Distribution of Schedule Buffer Float: Pre-Construction Activities

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Table 6-3. Distribution of Schedule Buffer Float: WOFH Section Activities

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Table 6-4. Distribution of Schedule Buffer Float: MSF Section Activities

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Table 6-5. Distribution of Schedule Buffer Float: Kamehameha Section Activities

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Table 6-6. Distribution of Schedule Buffer Float: Airport Section Activities

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Table 6-7. Distribution of Schedule Buffer Float: City Center Section Activities

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Table 6-8. Distribution of Schedule Buffer Float: Core Systems Activities

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Table 6-9. Distribution of Schedule Buffer Float: Project End Float

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6.3 Schedule Risk Model Results

The input data (ranges applied to the stripped schedule along with discrete risk events inserted into the schedule to model risk occurrence) is provided in Appendix F.

The results of the schedule risk analysis for the entire project are as described in Section 1. Table 6-10 through Table 6-12 and Figure 6-2through Figure 6-4 show the analysis results for each of the five key Sections:

- WOFH
- MSF
- Kamehameha
- Airport
- City Center

Table 6-10. Schedule Risk Results for Opening 1 Comprising WOFH Section, the MSF and Kamehameha Section

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Figure 6-2. Schedule Risk Analysis for WOFH Section

Table 6-11. Schedule Risk Results Opening 2 – Airport Section

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Figure 6-3. Schedule Risk Analysis for Airport Section

Table 6-12. Schedule Risk Results for Opening 3 – City Center Section

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Figure 6-4. Schedule Risk Analysis for Opening 3 – City Center Section

7 Minimum Project Contingency Capacity and Execution Plan

7.1 Preface and Introduction to Minimum Contingency Capacity

All projects face a multitude of risks, not just design and construction risks, but also legal, environmental, social, administrative, operational, and market-related risks. All of these risks could increase costs, cause delays, and draw-down a project owner's reserves or contingency very early during construction, thereby placing completion of the project at risk or making it financially unviable. The risks to delivery of transit mega-projects are well known and well understood by RTD and PB, particularly risks related to a transit project that is wholly or partially located in a city center or other congested locations.

The top-down model is specifically designed to challenge optimism bias at the early stages of a project's development but also to avoid reduction in contingency too quickly on the assumption risk had ended. By applying a BRF at any delivery milestone based on the beta reduction triangle, an estimate could be made of a minimum contingency that should remain to be reasonably confident of reaching revenue operations within the allocated budget. The FTA's goal is to ensure projects that started with an adequate contingency provision are protected should they subsequently run into financial difficulties by having a pre-developed plan to mitigate and replenish contingency to a minimum required level based on the targets arrived at through the top-down model analysis. The principles of the application of the BRFs are based upon progressive risk reduction, which follows a normal pattern in transit projects (Figure 7-1).

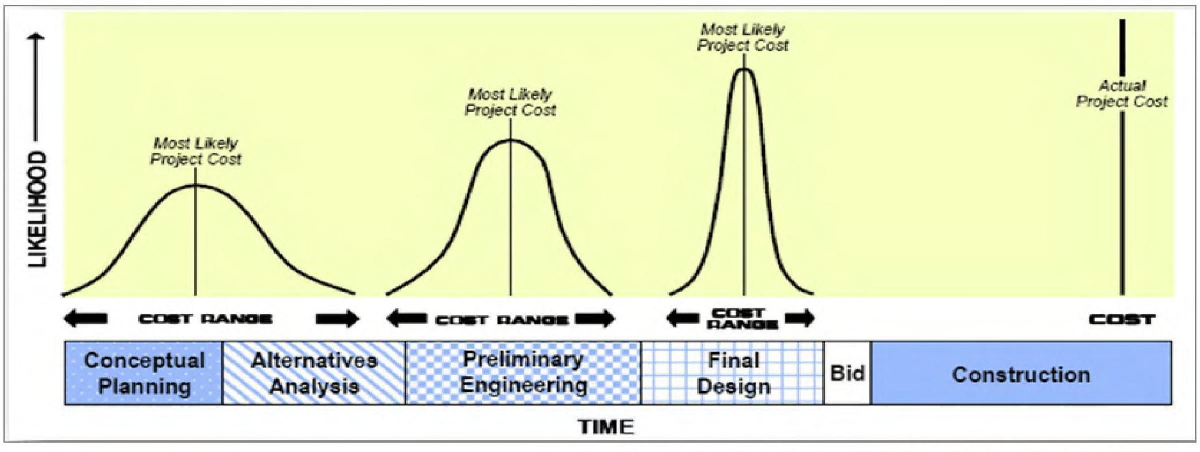

Figure 7-1. Progressive Risk Reduction

Risk reduction, however, can and does vary from one project to another. BRFs are therefore applied to align with the status of the particular project at each of the FTA milestones. There were a number of ongoing projects chosen to test the BRF application and refine the original model, determine what confidence levels should be set at any particular delivery milestone, and provide feedback to enable an Oversight Procedure to be developed.

As the Oversight Procedure evolved, the top-down model has been supported by what has been termed Forward Pass and Backward Pass analyses—adopting industry norms and physical calculation of potential claims given schedule slippage— to arrive at contingency amounts at identified points in the delivery cycle. These are then used to complement the top-down model (i.e., to validate or modify the figures produced using the BRFs).

In addition, FTA has introduced a more detailed approach to schedule forecasting based upon the Monte Carlo approach combined with the principles of progressive risk reduction that underlie the top-down cost model. Again the objective has been to validate a project sponsor's proposed schedule for delivery. After identification of schedule risks to the critical path, or near critical paths, intermediate contingency or float is identified to buffer the schedule against risk exposure. The project should have sufficient schedule contingency at entry into Final Design to absorb a schedule delay equivalent to 20 percent of the duration from the point of 100 percent bid through to revenue operation. This buffer float must be built into the project schedule to protect critical or near critical path activities by absorbing risk at various strategic points along the schedule.

The result of the cost and schedule risk analysis, the application of the BRFs, and the "forward and backward" pass analysis on the project's budget and schedule is a profiled time and cost contingency capacity diagram (Figure 7-2 and Figure 7-3). This serves as an ongoing management tool to be inserted into a Project Execution Plan and Contingency Management Plan complementing and forming part of the Project Management Plan to challenge early draw down of contingency capacity and to foster a culture of proactive risk mitigation.

Minimum contingency capacity has been assigned to FTA milestones. During the PE phase, "hold points"—intermediate strategic milestones occurring annually—will be developed as the contract management strategy is further refined and minimum contingency capacity is reassigned to represent the emerging and developing schedule.

FTA milestones are shown in Table 7-1.

Table 7-1. FTA Milestones (after Buffer Float)

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The dates set against the above milestones 1 through 4 are after the buffer float has been added to the stripped and adjusted schedule. They are not the RTD current plan dates. The dates set against the above milestones 5 through 8 are taken from a cash flow based on a RCD of June 2019. This is based on six months of end float.

The intention is that minimum contingency capacity is required to be drawn down against buffered schedule dates. It is understood that FTA is receptive to re-baselining the hold point dates in the event earlier completion of scope related to a particular milestone is achieved.

7.2 Cost Minimum Contingency Capacity

The Project does not fit into the FTA OP 40 standard delivery model. The current FTA milestone representing the closest status to the Project at the time of this risk assessment is believed to be “40 percent bid.” FTA’s OP 40 anticipates that this is achieved normally following the approval of an FFGA and is associated with a target confidence factor of 60 percent. At the time of this risk assessment, the Project has not been granted a ROD, has not acquired any right-of-way, and has not been given approval to enter Final Design by FTA. However, the Project has bid and either awarded, is in the process of obtaining BAFO for, or is in final negotiations on contract scope with a combined value equal to more than 40 percent of the current

BCE (YOE). The resulting current risk profile is significantly different to the standard FTA model that OP 40 is drafted against.

It has therefore been necessary to propose adjustments to the OP 40 target confidence values to more accurately reflect the risk exposure and BRF values assigned at the various milestones. Table 7-2 shows the FTA OP 40 target values and, on the right, the proposed adjusted target values. The notes at the bottom of the table expand upon the expected status of the Project at the earlier milestones (1 through 4), which are believed to require adjustment.

Table 7-2. FTA Target and Adjusted Target at Milestones

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At the current milestone, 40 percent bid, the analysis shows a shortfall in contingency capacity of $145 million. Assuming perfect mitigation, the contingency capacity required to support future milestones is shown to be sufficient. This analysis supports the view that once a ROD is secured, contracts have been awarded for the Kamehameha guideway and Core Systems, and acquisition of right-of-way has begun, significant risk exposure is removed. The granting of LONPs to support an early start to construction immediately following an approval of formal entry into Final Design will reduce risk exposure to additional delay claims from awarded contracts and reduce risk exposure and pressure on the Project's finances and cash flow.

Table 7-3 (all figures $ millions) shows the forward and backward pass analysis, the RTD planned draw down of contingency, and the buffer zone representing an amount 25 percent above the minimum at each milestone. RTD's minimum contingency capacity has been calculated using the 50th percentile confidence value extracted from the bottom-up cost analysis and drawn down by calculating the top-down BRF model reducing contingency balance from the top-down analysis.

Table 7-3. Minimum Cost Contingency Capacity for Cost Graphic

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The backward pass analysis commences from a point requiring contingency capacity to withstand a potential delay from the RTD target revenue service date of July 2019 to a potential delayed revenue service date of January 2020 (the proposed FTA/RTD reserve date) using an average cost equivalent to approximately $6 million per month (based on a conservative estimate extracted from the schedule delay factor calculated in the bottom-up cost model).

Figure 7-2 shows the Project's cost graphic depicting the progressive draw down of contingency through the FTA milestones along with the minimum contingency capacity at any particular milestone to be held by RTD as reserve below which mitigation is required to replenish the minimum. The minimum contingency values are extracted in Table 7-4.

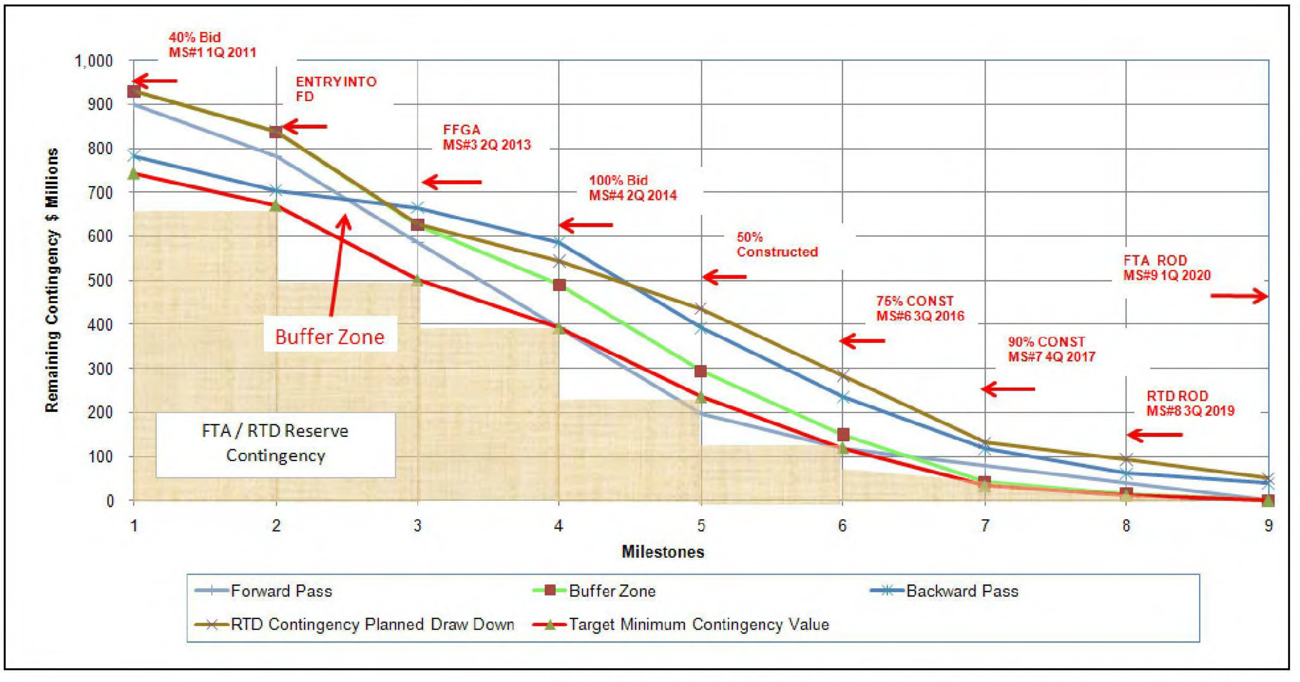

Figure 7-2. Minimum Contingency Cost Graphic

Table 7-4. Project Milestones with Minimum Cost Contingency

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7.3 Schedule Minimum Contingency Capacity

Table 7-5 shows the forward and backward pass analysis, the RTD planned draw down of schedule float contingency, the FTA target minimum contingency capacity, and the buffer zone representing an amount 25 percent above the minimum at each milestone. These numbers are illustrated in Figure 7-3.

Table 7-5. Minimum Schedule Contingency Capacity for Schedule Graphic (Figure 7-3)

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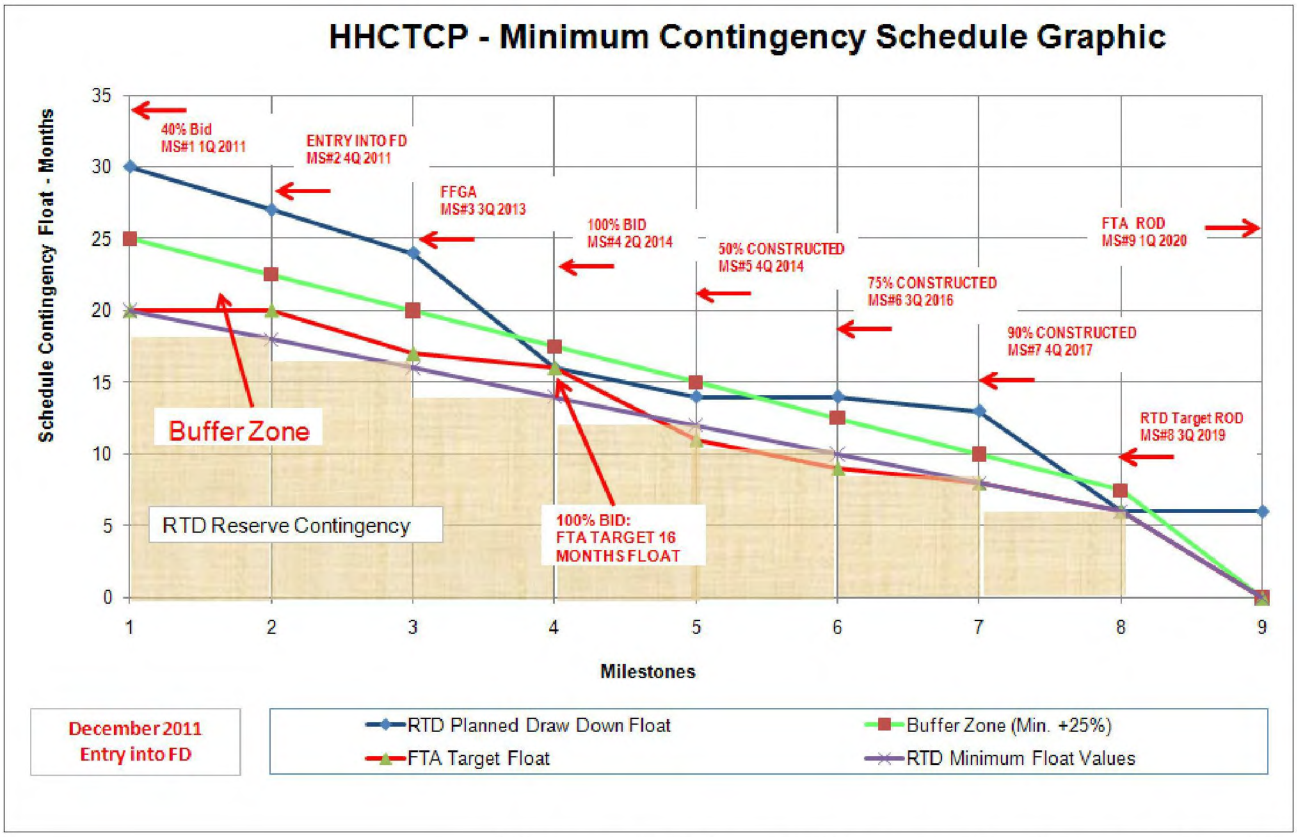

Figure 7-3. Schedule Minimum Contingency Graphic

Table 7-6 shows the minimum schedule contingency (schedule float) required at each of the project milestones

Table 7-6. Project Milestone with Minimum Schedule Contingency

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8 Risk Mitigation and Risk Management Plan

8.1 Risk Management Plan

As the Project develops through Final Design, risks that remain will be allocated in part or whole through the contractual arrangements and bidding process with an awareness that risks should be assigned and owned by the party best able to manage that risk and that transfer of unmanageable risk is either met with budget overages or an unwillingness by the contracting industry to accept the risk. This risk analysis assumes the ultimate fair and proper allocation of risk.

8.2 Risk Mitigation

In order to mitigate the potential greatest cost and/or schedule risks to the Project, the risk workshop discussed and developed the following mitigations:

Section to be completed in consultation with PB and RTD.

Appendix B
Project Risk Register

Appendix F
Stripped Schedule

Appendix G
Schedule QSRA

Appendix H
Risk Methodology Presentation

Appendix I
Locations of 132 kV Conflicts